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ABSTRACT

Described are some of the better techniques for installing solar domestic hot water (DHW) systems. By using these guidelines, along with the manufacturer's manual, professional installation contractors and skilled homeowners should be able to install and fill a solar DHW system. Among the topics considered are system layouts, siting, mounting procedures, pipes, insulation, heat exchangers, system controls, and safety. The manual also contains maintenance suggestions and an installation checklist. (WB)

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U.S. Department of Housing and Urban Development
Office of Policy Development and Research
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Installation Guidelines for Solar DHW Systems

In One-and Two-Family Dwellings

Second Edition

SE 033 061

INSTALLATION GUIDELINES FOR SOLAR DHW SYSTEMS IN ONE- AND TWO-FAMILY DWELLINGS

SECOND EDITION

by

Franklin Research Center
Philadelphia, PA

for

Division of Energy, Building Technology and Standards
Office of Policy Development and Research
U.S. Department of Housing and Urban Development
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FOREWORD

Installation Guidelines for Solar Domestic Hot Water Systems is the first in a series of instructional reports to be published by the U.S. Department of Housing and Urban Development (HUD). It is the direct outgrowth of the Residential Solar Demonstration Program and a series of installation workshops funded by HUD and the Department of Energy.

Over the past few years, thousands of publicly and privately funded solar energy systems have been installed across the country. From this experience, some installation techniques have emerged as being superior to others. At the same time, many systems have failed to perform properly due to poor installation practices. The intent of this report is to present some of the better installation techniques.

The report is written for the professional installation contractor and the skilled homeowner. The installation of a solar energy system involves a combination of many traditional construction skills including plumbing, wiring, roofing, carpentry, and masonry, as well as knowledge of paints, glazing, and insulation materials. We assume you already possess these basic skills (see Appendix B). Even with these skills, professionals in the demonstration program have made simple mistakes, which we intend to help you avoid.

Using these guidelines together with the manufacturer's manual, you should be able to install and fill your solar domestic hot water system. These guidelines also contain pointers for maintenance and a checklist to be consulted when doing the actual installation.

All of the procedures outlined in the report comply with HUD's Intermediate Minimum Property Standards Supplement, Solar Heating and Domestic Hot Water Systems, Volume 5 (4930.2) (IMPS). The guidelines are compatible with most national building codes. However, you must check with local building authorities to make sure you comply with the code, permit, zoning, and license regulations in your area (see Appendix D).

Finally, keep in mind that this manual deals with solar domestic water heating systems in general. It is essential to consult the instruction manual from the manufacturer, to correctly install a particular system.

NOTE: Throughout this book, the reader will see a series of indicators calling attention to crucial steps in the installation of a solar domestic hot water system. They are:

NOTE:

CAUTION!, and

WARNING!

A **NOTE:** will point out a procedure or action that, if omitted, might lead to a reduction in the overall efficiency or attractiveness of the system. A **CAUTION!** will point out a procedure or action that, if omitted, might lead to damage of solar or other heating, ventilating, and air conditioning (HVAC) equipment or other property. **WARNING!** will point out a procedure or action that, if omitted, might lead to conditions threatening the personal safety of homeowners, pedestrians, or solar service personnel.

START-UP, SYSTEM LAYOUT, AND SITING

START-UP

All major components of the solar domestic hot water (DHW) system you will be installing will have been specified by the system designer or kit manufacturer as a rule. Before beginning the installation, you should obtain the following information:

The Supplier

Has the supplier of the major system components been selected? Is there a dealership or distributorship near the job site? Can you get help from the supplier if needed? Are replacement parts easily available? Can you count on the supplier's delivery schedule? You can obtain some of this information from the supplier's other customers.

Legal Preparations

Has a building permit been taken out, if required? Have you complied with zoning requirements? Which building codes will require inspection of this installation? Will a licensed plumber be required to connect the plumbing system? Will a licensed electrician be required to make the electrical connections?

Is the system going to be federally funded or insured (FHA, VA, FmHA)? If so, it must meet the requirements of the U.S. Department of Housing and Urban Development's Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems, Volume 5 (IMPS) (Figure 1.1). This document is useful to any professional solar installer. It is available as a subscription for $12.00 from the Superintendent of Documents, U.S. Government

HUD
INTERMEDIATE
MINIMUM
PROPERTY
STANDARDS
SUPPLEMENT

SOLAR HEATING
AND DOMESTIC
HOT WATER SYSTEMS

FIGURE 1.1: INTERMEDIATE MINIMUM PROPERTY STANDARDS (IMPS)

Printing Office, Washington, DC 20402. Please be sure that the stock number, Number 4930.2, is included on your order.

Read the manufacturer's warranty statements on the major components and note your responsibilities. Some manufacturers' warranties are only good if the systems are installed according to their instructions. Some installers offer warranties for systems they install. If you plan to follow this practice, you must understand the legal implications of your warranty.

Inventory Components

Check each component against your receipts to make sure all parts ordered have arrived and are in good condition. Plan the job with the manufacturer's manuals in hand to do the work most effectively.

SYSTEM LAYOUT

The layout of the system you are installing probably has been specified by the designer. A few layout options are presented here for your information and to help you visualize the sequence of assembly.

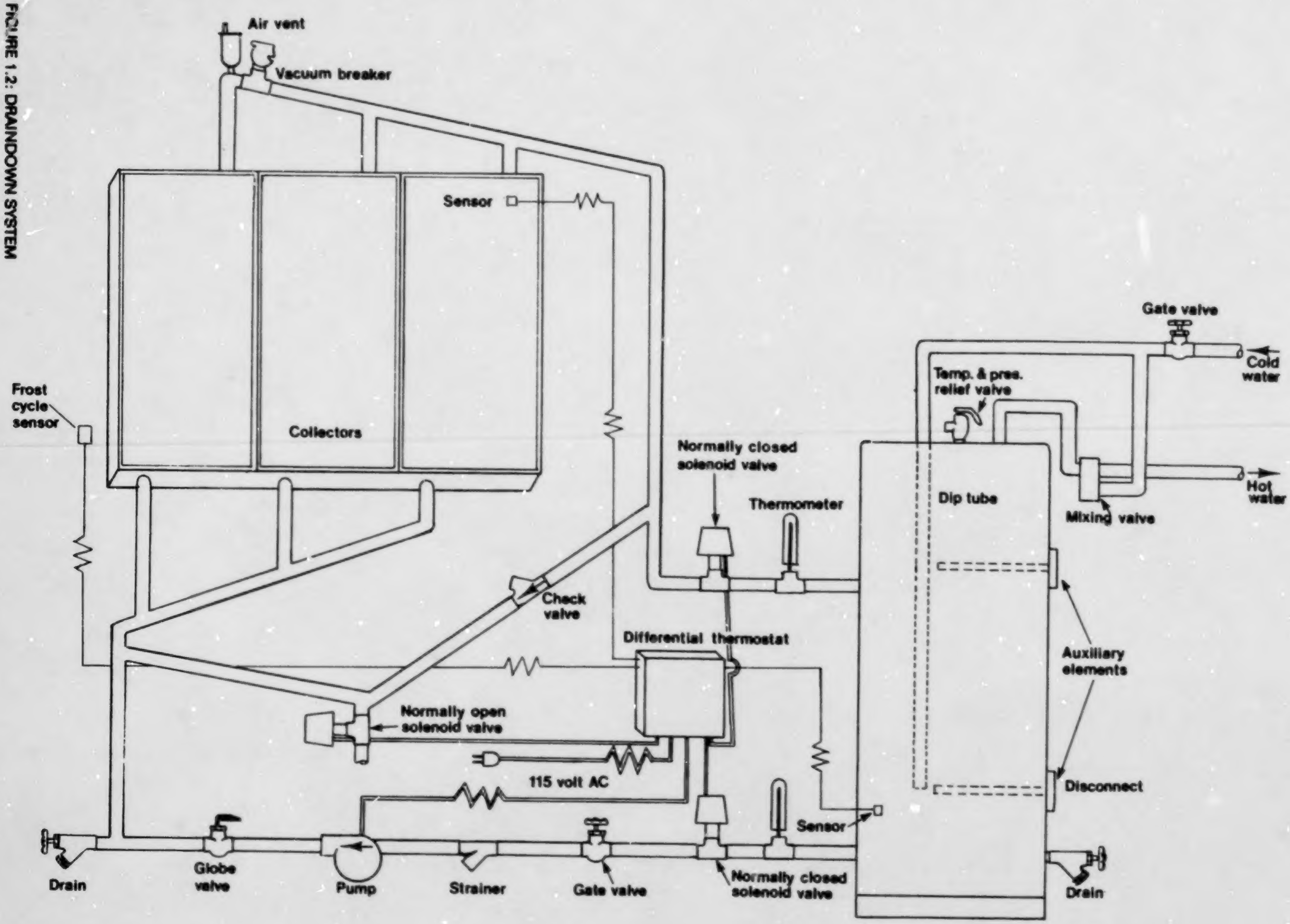
Draindown System

Potable water is circulated from the storage tank through the collector loop. Freeze protection is provided by solenoid valves opening and dumping water at a preset low temperature (Figure 1.2). Collectors and piping must be pitched so that the system will automatically drain down, even in a power failure. This type of system is exposed to city water line pressures and must be assembled carefully to withstand pressures as high as 100 psi. Pressure reducing valves are recommended when city water pressure is greater than the working pressure of the system.

Drainback System

The solar heat transfer fluid automatically drains into a tank by gravity (Figure 1.3). Drainback systems are available in one- or two-tank configurations. A heat exchanger is necessary, because the city water inlet pressure would prevent draining. The heat transfer fluid in the collector loop may be distilled or city water if the loop plumbing is copper. If the plumbing is threaded galvanized pipe, inhibitor may be added to prevent corrosion. Most inhibitors are non-potable and require a double wall heat exchanger. The pump used must be sized to overcome static head (see chapter on Pumps, etc.).

FIGURE 1.2: DRAINDOWN SYSTEM


Air vent
Vacuum breaker
Sensor
Collectors
Frost cycle sensor
Check valve
Differential thermostat
Normally open solenoid valve
115 volt AC
Normally closed solenoid valve
Thermometer
Gate valve
Cold water
Temp. & pres. relief valve
Dip tube
Mixing valve
Hot water
Auxiliary elements
Disconnect
Sensor
Drain
Globe valve
Pump
Strainer
Gate valve
Normally closed solenoid valve
Drain

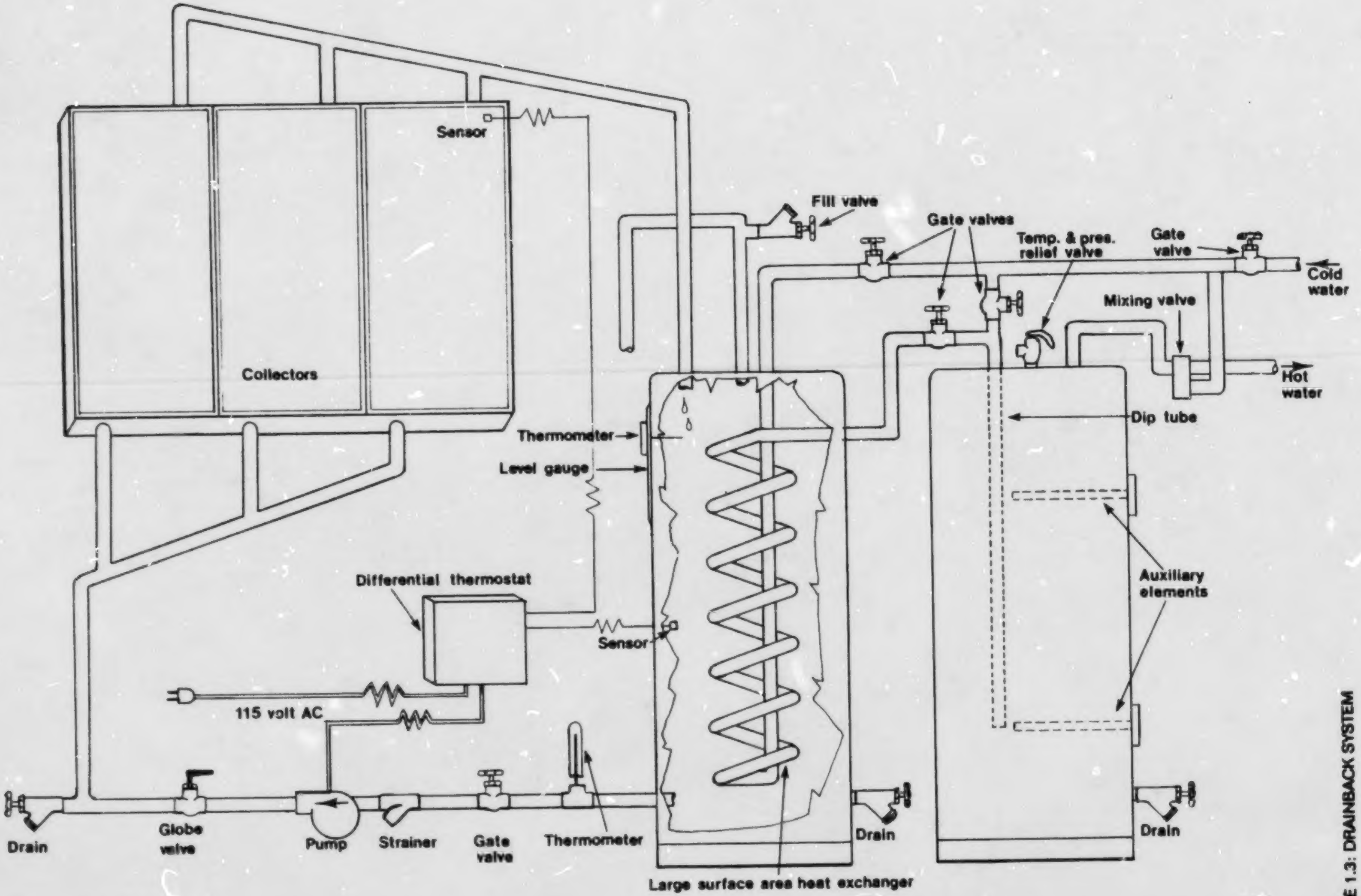

Sensor
Collectors
Fill valve
Gate valves
Temp. & pres. relief valve
Gate valve
Cold water
Mixing valve
Hot water
Dip tube
Thermometer
Level gauge
Auxiliary elements
Differential thermostat
Sensor
115 volt AC
Drain
Globe valve
Pump
Strainer
Gate valve
Thermometer
Drain
Drain
Large surface area heat exchanger

FIGURE 1.3: DRAINBACK SYSTEM

One-Tank Closed-Loop System

A conventional DHW tank, usually electrically heated, is converted to a solar DHW storage tank by installing an external heat exchanger coil. The lower electrical heating element is removed, leaving the uppermost of the usual two elements to provide auxiliary water heating and to achieve good stratification (layering of hotter water over progressively colder water). Solar tanks equipped with internal heat exchangers are now readily available (Figure 1.4). Usually, the heat transfer fluid is a water/glycol mixture or some other freeze-resistant fluid, such as silicone or a hydrocarbon (see chapter on Transfer Fluids).

Two-Tank Closed-Loop System

One-tank systems may be sufficient for small families with small hot water needs, but most retrofit projects will call for installing a second tank connected in series with and preceding the conventional DHW tank already in place (Figure 1.5). Two tanks often return cooler water to the collectors for heating, allowing them to operate more efficiently. However, standby losses are greater.

Thermosiphon System

Thermosiphon systems are the oldest type of solar DHW system. These systems do not depend on electric power to pump the heat transfer fluid (potable water) through the collector array. The storage tank is positioned at least 18"-24" above the upper end of the collector array, and the heated water in the collectors flow up to the top of the storage tank by natural convection. Hot water is drawn off the top of the tank. Cold city water is fed into the bottom of the tank and then descends to the bottom of the collector array to be heated. (Figure 1.6) Thermosiphon systems are often impractical in freezing climates. However, thermosiphon systems are simple and relatively inexpensive and would be ideal in warmer climates or for summer time use.

Air System

Solar domestic hot water systems employing air-type collectors are available. Hot air generated by these collectors is fan forced through an air-to-liquid heat exchanger with the potable water being pumped through the liquid section of the exchanger. The heated water is then circulated through the storage tank in a similar fashion to the liquid collector system. (Figure 1.7) Air does not need to be protected from freezing or boiling, is non-corrosive, and is free. However, air ducts and air handling units require greater space than piping, and air leaks are difficult to detect.

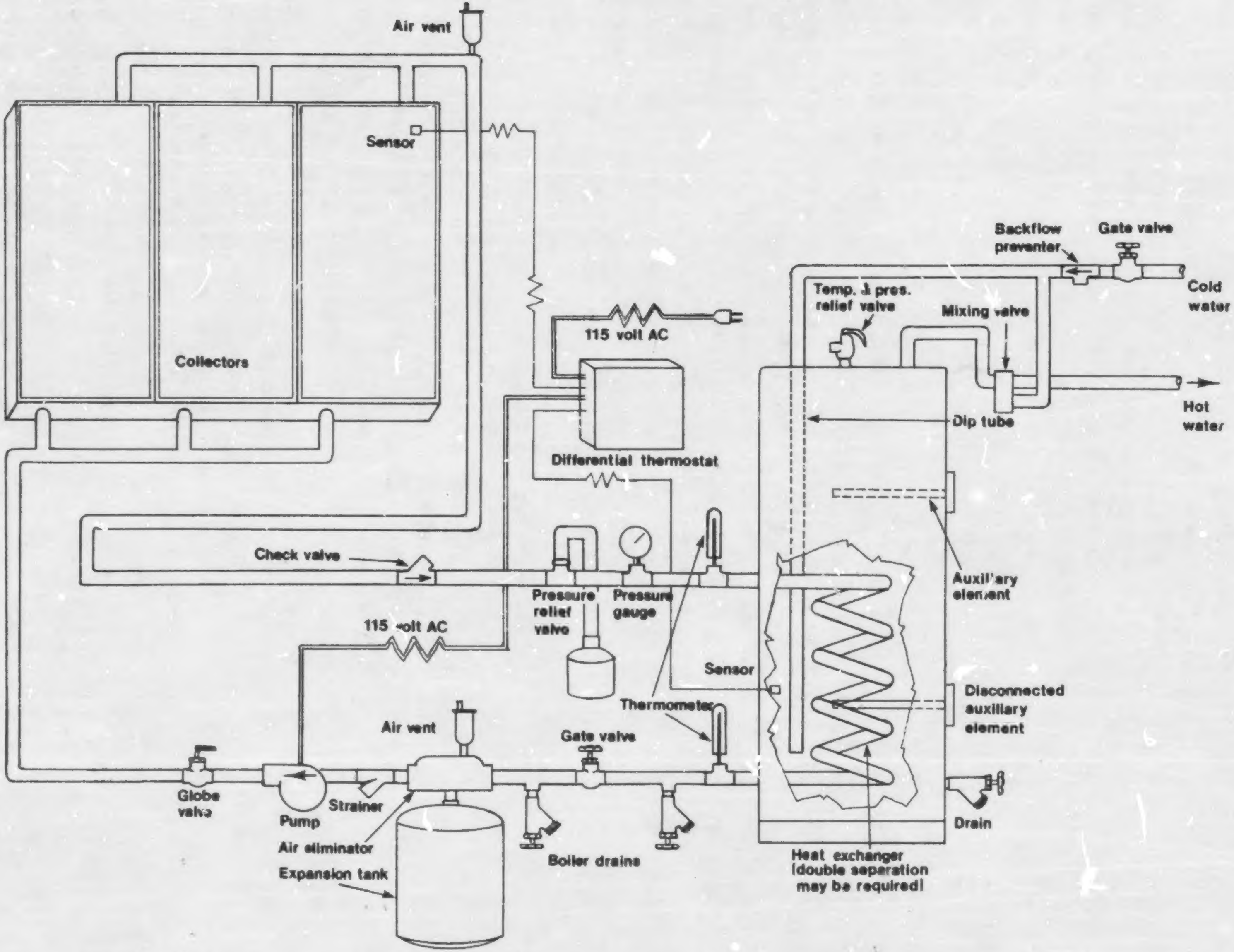

Air vent
Sensor
Collectors
115 volt AC
Differential thermostat
Check valve
Pressure relief valve
Pressure gauge
115 volt AC
Sensor
Thermometer
Air vent
Gate valve
Globe valve
Pump
Strainer
Air eliminator
Expansion tank
Boiler drains
Backflow preventer
Gate valve
Cold water
Temp. & pres. relief valve
Mixing valve
Hot water
Dip tube
Auxiliary element
Disconnected auxiliary element
Drain
Heat exchanger (double separation may be required)

FIGURE 1.4: CLOSED LOOP SYSTEM—ONE TANK

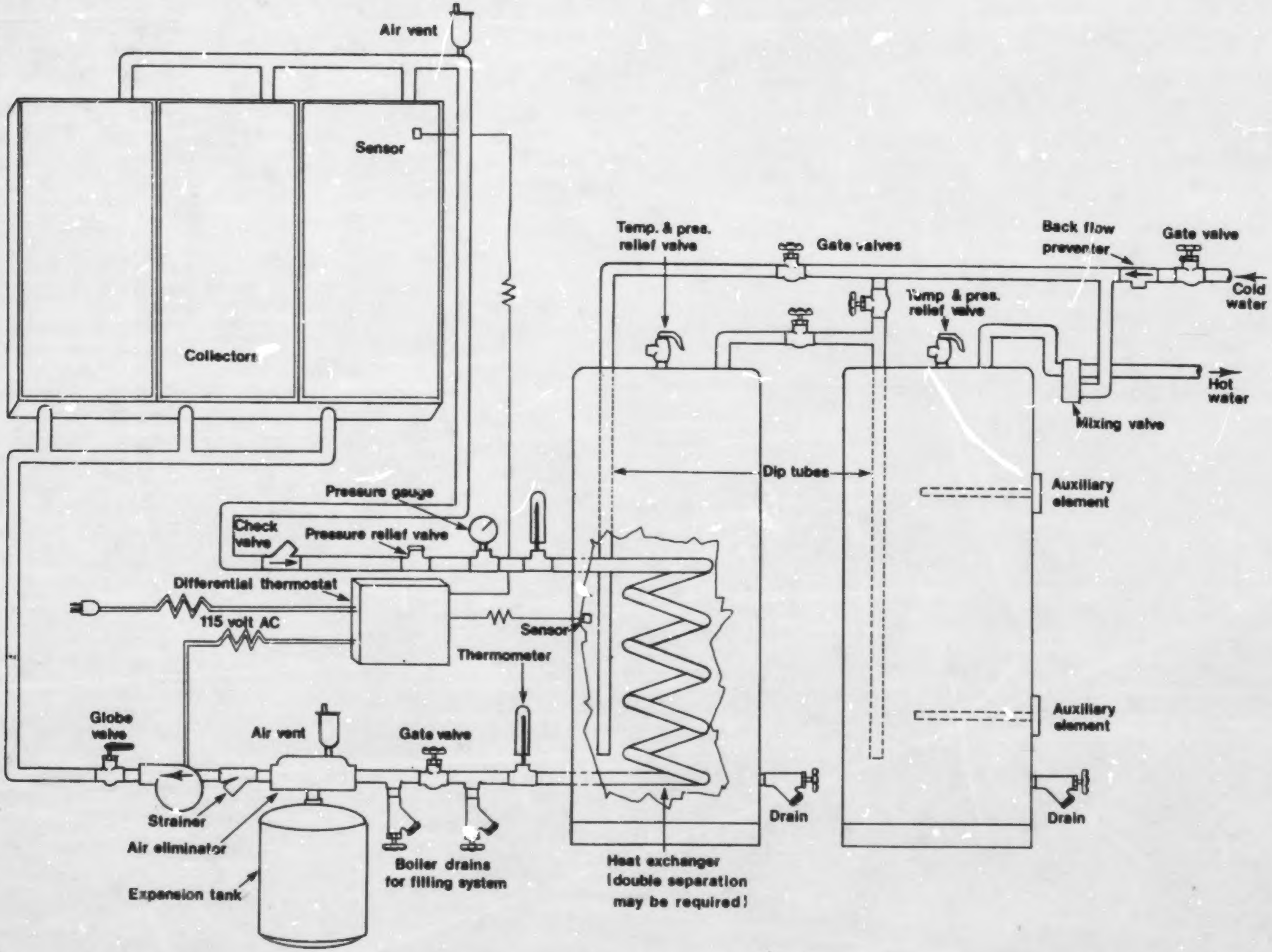

Air vent
Sensor
Collectors
Temp. & pres. relief valve
Gate valves
Back flow preventer
Gate valve
Cold water
Temp & pres. relief valve
Hot water
Mixing valve
Dip tubes
Auxiliary element
Pressure gauge
Check valve
Pressure relief valve
Differential thermostat
115 volt AC
Sensor
Thermometer
Auxiliary element
Globe valve
Air vent
Gate valve
Strainer
Air eliminator
Expansion tank
Boiler drains for filling system
Drain
Drain
Heat exchanger (double separation may be required)

FIGURE 1.5: CLOSED LOOP SYSTEM—TWO TANKS

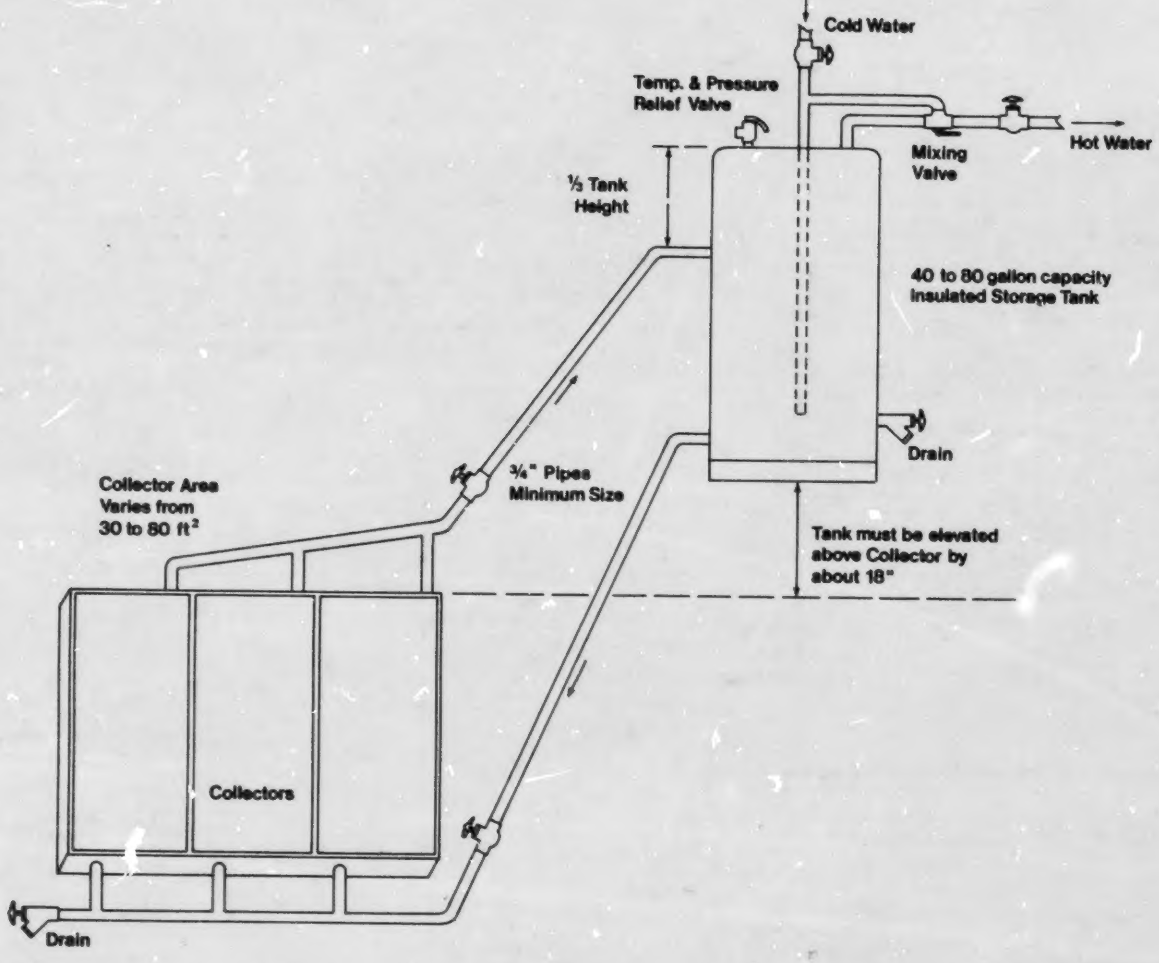

Cold Water
Temp. & Pressure Relief Valve
Mixing Valve
Hot Water
⅓ Tank Height
40 to 80 gallon capacity Insulated Storage Tank
Drain
¾" Pipes Minimum Size
Collector Area Varies from 30 to 80 ft²
Tank must be elevated above Collector by about 18"
Collectors
Drain

FIGURE 1.6: THERMOSIPHON SYSTEM

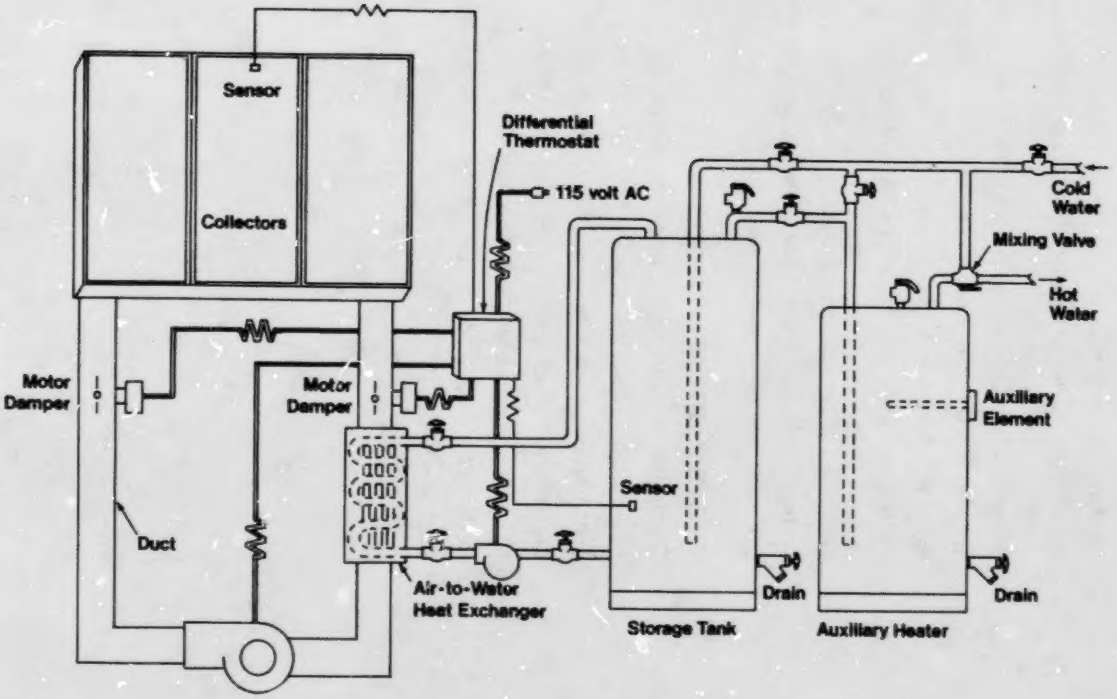

Sensor
Collectors
Differential Thermostat
115 volt AC
Cold Water
Mixing Valve
Hot Water
Motor Damper
Motor Damper
Auxiliary Element
Sensor
Duct
Air-to-Water Heat Exchanger
Drain
Drain
Storage Tank
Auxiliary Heater

FIGURE 1.7: AIR SYSTEM

Other Systems

A number of system types are found only in limited areas or in custom-designed or do-it-yourself projects.

Manual draindown systems use potable water for the heat transfer fluid without any antifreeze additives. The owner has to operate the draindown valve manually. These systems can be operated only in regions or during seasons when there is little chance of a freeze.

Reverse-trickle, or pulse-circulation, systems pump a quantity of hot water from the storage tank into the collector array (lowering system efficiency) when there is danger of a freeze. This type of system is very popular in Florida and southern California.

There are also draindown systems which use air pressure in the storage tank or in a separate pressure tank to force water out of the collectors when a freeze threatens.

SYSTEM SITING

Place the collector array where it will receive the maximum amount of sunlight available in your location. A roof mount is the most common because it reduces the chances of shading and keeps the collectors out of the way. If a good roof area is not available, collectors may be ground-mounted (see chapter on Mounting Procedures). Keep outdoor pipe runs to a minimum to avoid energy losses.

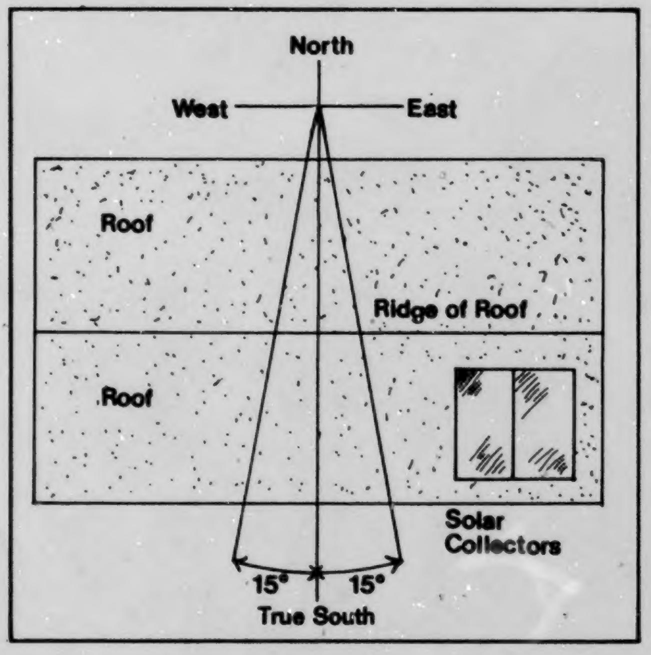


FIGURE 1.8: COLLECTOR ORIENTATION

Collector Orientation

It is desirable to mount the collectors to catch as much of the sun's daily rays as possible. Ideally, collectors should be aimed as nearly as possible TRUE south, not magnetic south. However, variations of up to 15° east or west of south will have little effect on performance, if the system is running properly (Figure 1.8). It is not worth the added expense to build a special mounting frame to point collectors true south if the roof is pointed within the ±15° limits. Beyond 15°, additional calculations must be performed to determine if the expense is justified. Deviations up to 30° east or west of south will usually decrease performance by only 10%. After that, performance drops dramatically.

Because the earth's magnetic field is not aligned parallel with the earth's north-south axis, there are some parts of the United States where the needle of a magnetic compass can point as much as 20 degrees east or west of true north. However, there are several ways to determine true south in your area. You can consult a local surveyor, a plot map in your local tax office, or a recent isogonic chart of the United States published by the U.S. Coast and Geodetic Survey, U.S. Department of Commerce (Figure 1.9) and adjust your magnetic compass reading according to the meridian nearest to you. Don't use old charts, as there are annual variations in the readings. When using a magnetic compass, beware of stand-

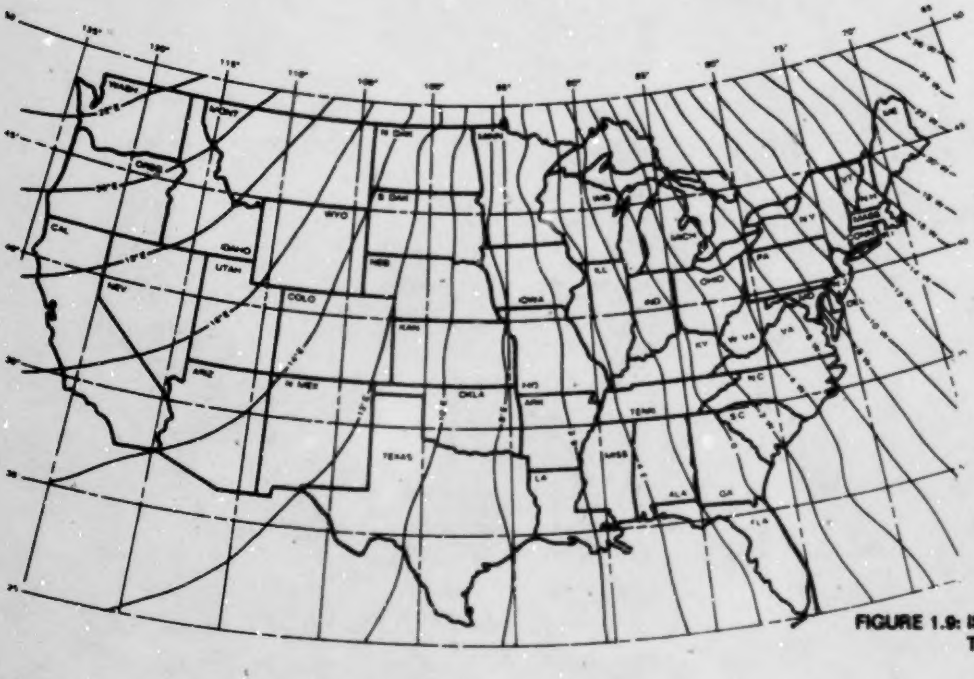


FIGURE 1.9: ISOGONIC CHART OF THE U.S.

ing near large metallic objects or power lines because they will affect the compass readings.

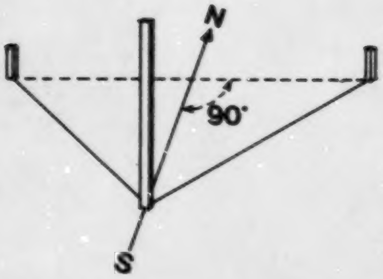


FIGURE 1.10: STAKE AND SHADOW METHOD

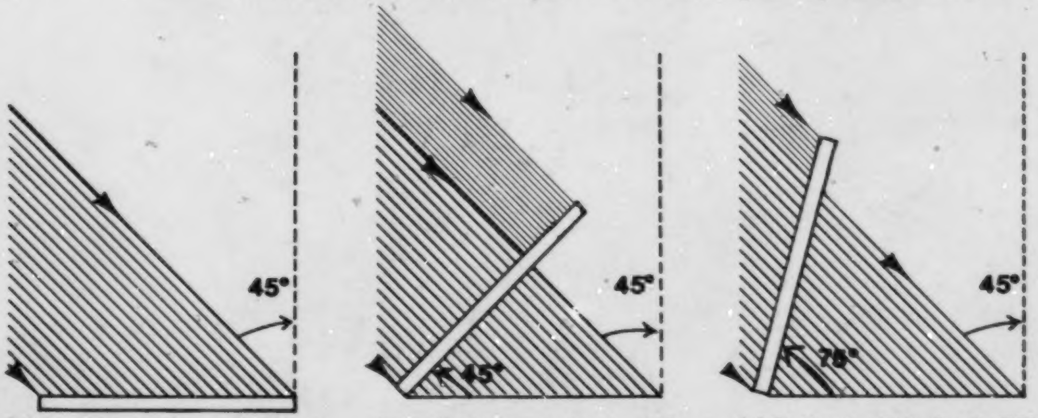
Also, you can easily determine true south yourself right at the installation site. Place a stake in the ground and mark the location of the shadow of the top of the stake. Connect the end point of a morning shadow with the end point of an afternoon shadow by a straight line. A line drawn 90° to that line is a true north-south line (Figure 1.10).

There is an even faster way to determine your local north-south line. The shadow of a stake cast by the sun at solar noon will be on the true north-south line. Solar noon is exactly halfway between sunrise and sunset on any given day. Most local TV weather shows and newspapers give the exact times of sunrise and sunset each day.

Although performance will not be substantially affected, take local weather conditions into consideration when deciding on collector orientation. Although angling the collectors toward the east will start the system earlier in the morning, orientation slightly to the west can increase system performance because ambient temperatures are usually higher in the afternoon. As a result, collectors will lose less heat and operate more efficiently. If early morning fogs are common in your area, angle the collectors slightly toward the west.

Collector Tilt

Collector tilt—the angle the surface of the collector makes with the horizon—is also an important factor in system performance. Ideal-



(a) Collector Tilt Angle 0° (b) Collector Tilt Angle 45° (c) Collector Tilt Angle 75°

☰ Radiation Intercepted by a Horizontal Collector

▤ Additional Radiation Intercepted by Tilting Collector

FIGURE 1.11: RADIATION ON HORIZONTAL, NORMAL AND NEARLY VERTICAL SURFACES

ly, collectors should be as nearly perpendicular to the sun's hottest rays as possible (Figure 1.11). For a solar DHW system, a tilt equal to the local north latitude usually is considered the optimum angle. Variations 10° either way will not seriously affect the total annual performance of the system, all other things being equal, but a greater tilt will favor winter system operations when the sun is low in the sky (Figure 1.12). Also, in heavy snow areas a tilt of 50° will allow snow to slide off the collectors more readily (see chapter on Safety). The following chart will help you determine the angle of the existing roof:

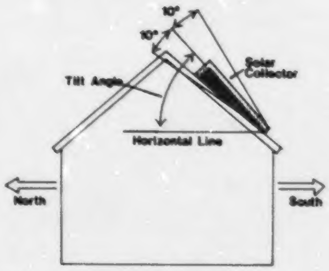


FIGURE 1.12: COLLECTOR TILT

TABLE 1.1 ANGLE/ROOF PITCH CONVERSION TABLE

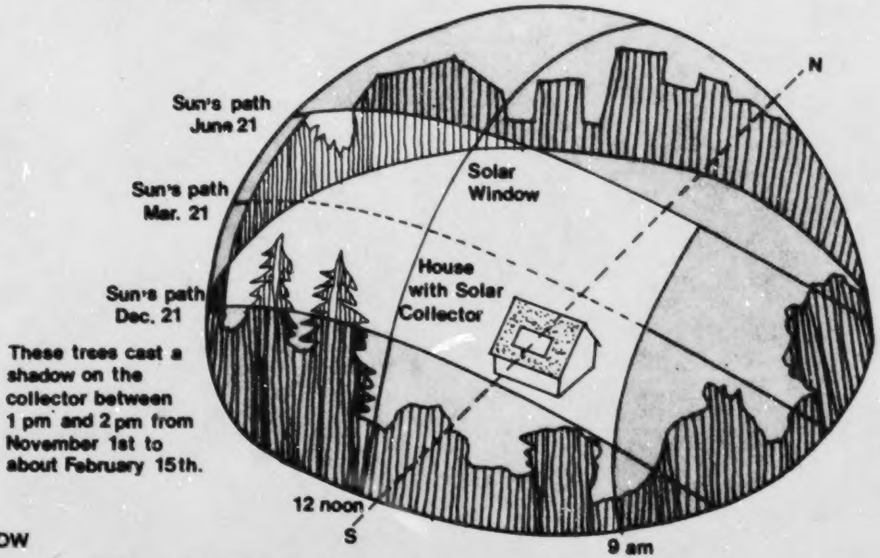
ANGLE (DEGREES)	ROOF PITCH
5	1/12
10	2/12
14	3/12
18	4/12
23	5/12
27	6/12
30	7/12
34	8/12
37	9/12
40	10/12
43	11/12
45	12/12
47	13/12
49	14/12
51	15/12
53	16/12

Collector Shading

No more than 5% of the collector area should be shaded between 9:00 A.M. and 3:00 P.M. Standard Time when greatest solar potential occurs. One of the major sources of shading is trees, so the home owner should be aware of the effect of future growth. Chimneys, dormers, other buildings, new construction, and even fences may shade the collector array, especially in the winter when sun angles are low and shadows are long. By knowing the altitude (angle of sun above horizon) and the azimuth (angle between true south and point on horizon below sun) of the sun throughout the year, you can accurately determine if the homeowner is going to have shading problems (see Appendices A and C).

The Solar Window

Imagine the sky as a transparent dome with its center at the solar collector array of a house. The path of the sun during the year can be etched (projected) on the dome, as can the outline of surrounding houses and trees (Figure 1.13). The sun's path during the optimum hours between 9:00 A.M. and 3:00 P.M. Standard Time throughout the year scribes a "solar window" on the dome. Almost all of the useful sunlight that reaches the collector array must come through this window, except for the amount resulting from diffuse radiation. If any surrounding houses, trees, hills, etc. block part of this window, that intrusion will cast a shadow on the collector. The elevation of the solar window in the local sky will decrease with increasing latitude.



These trees cast a shadow on the collector between 1 pm and 2 pm from November 1st to about February 15th.

FIGURE 1.13: THE SOLAR WINDOW

Mercator Projection

The sky dome with its "solar window" can be mapped using a Mercator projection in which the latitude and longitude lines are straight (Figure 1.14). Such a map is very useful for comparing the

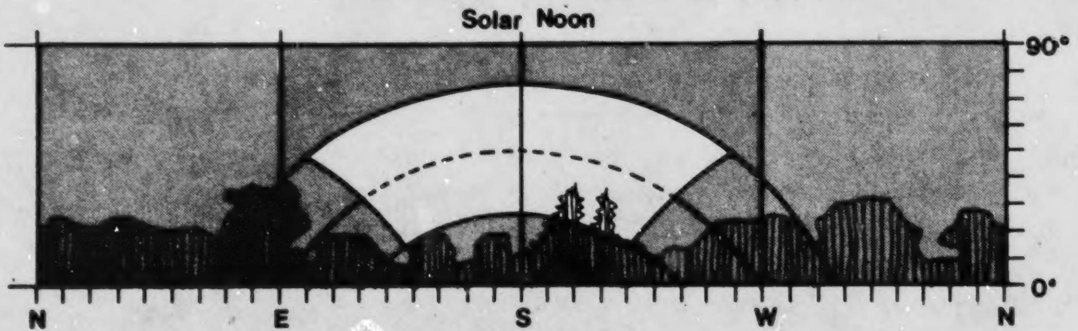
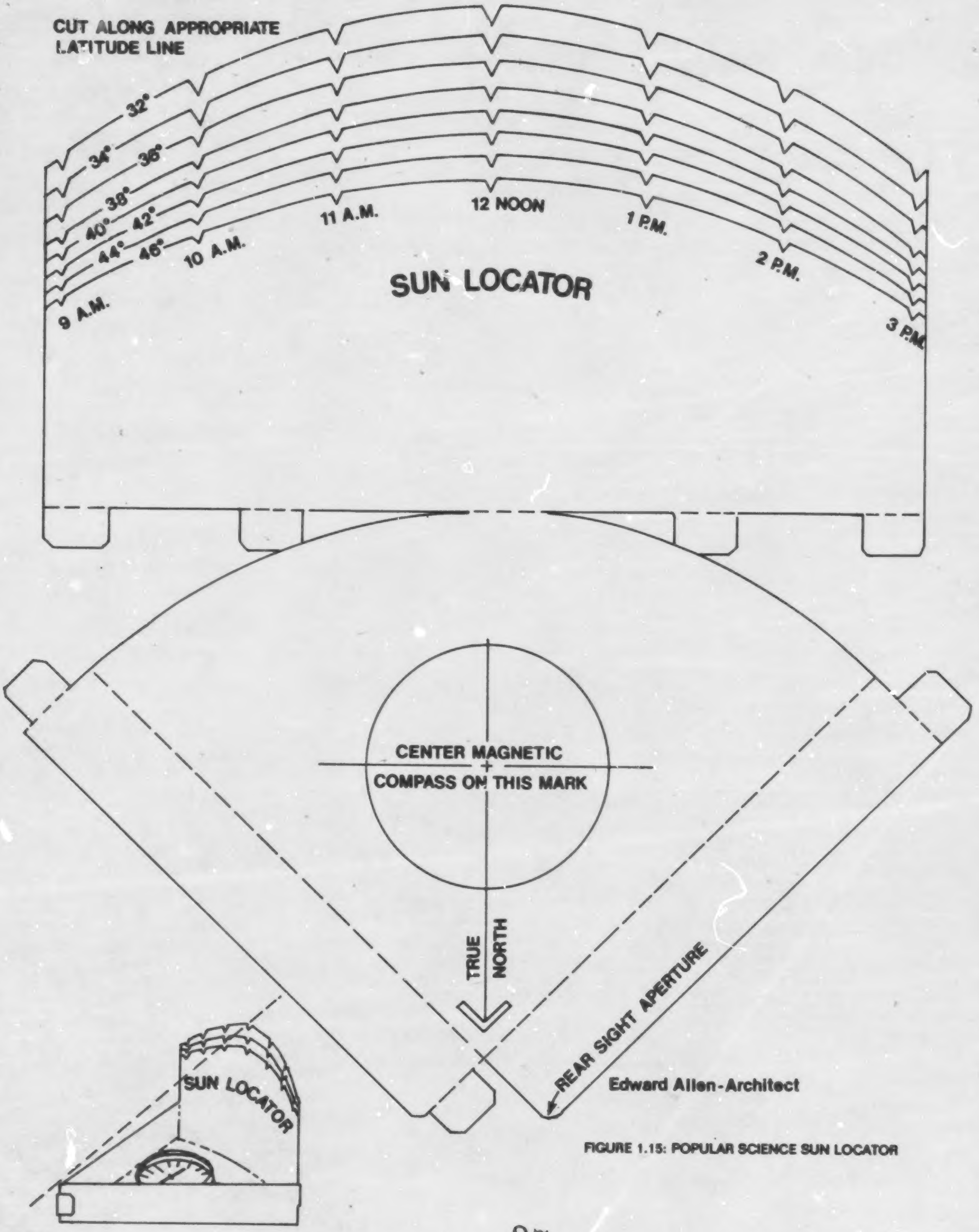


FIGURE 1.14: MERCATOR PROJECTION


CUT ALONG APPROPRIATE LATITUDE LINE
32°
34°
36°
38°
40°
42°
44°
46°
9 A.M.
10 A.M.
11 A.M.
12 NOON
1 P.M.
2 P.M.
3 P.M.
SUN LOCATOR
CENTER MAGNETIC COMPASS ON THIS MARK
TRUE NORTH
REAR SIGHT APERTURE
SUN LOCATOR

Edward Allen-Architect

FIGURE 1.15: POPULAR SCIENCE SUN LOCATOR

site surroundings with the "solar window", because both can be easily plotted on the map. Any elements surrounding the site that intrude into the "solar window" will cast shadows on the collector.

The Popular Science Sun Locator

A simpler method was created for Popular Science Magazine*. Make a copy of the sun locator (Figure 1.15) and glue it to a cardboard backing. Trim along the line of the latitude nearest you. Place locator in a level position in the area where collectors are to be mounted. Align the compass along the correct magnetic declination line or per a recent isogonic chart (Figure 1.7) to obtain a true north-south line (see Collector Orientation). Sight from the corner over the top of the latitude line from 9:00 A.M. to 3:00 P.M. This is a path the sun will take in midwinter. If more than 5 percent of the path is blocked, the site may need closer evaluation.

Even tree branches without leaves can block a considerable amount of winter sunlight if the branches are thick. Consider trimming, if necessary.

The Energy Task Force Rough Approximation Method

The Energy Task Force of New York suggests a way of roughly determining the solar window. Stand where the collectors are to be placed and face true south. Point so that your finger and your eye are horizontal (Figure 1.16). Place one fist on top of another the exact number of times to be determined by consulting the table (Table 1.2).

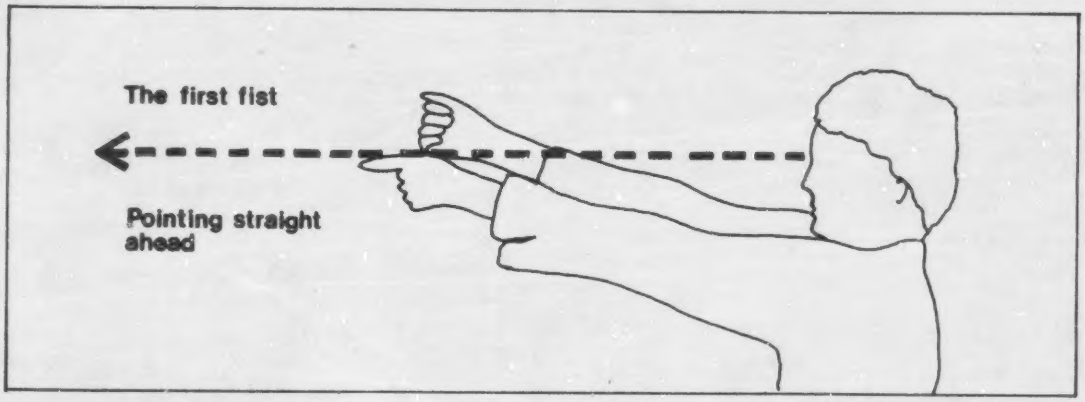


FIGURE 1.16: POINTING LEVEL WITH EYE

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* See Solar Energy Handbook 1978. Popular Science, Times Mirror Magazines, Inc., 380 Madison Ave., New York, NY 10017 . . . $1.95.

TABLE 1.2. THE ENERGY TASK FORCE SOLAR WINDOW APPROXIMATION METHOD*

LATITUDE	12 O'CLOCK POSITION = 0° BEARING	11 O'CLOCK POSITION = 30° BEARING ANGLE (EAST)	1 O'CLOCK POSITION = 30° BEARING ANGLE (WEST)
28°N	4½ FISTS (47° ALT.)	3 FISTS (30° ALT.)	SAME AS 11 O'CLOCK
32°N	3½ FISTS (34° ALT.)	2½ FISTS (26° ALT.)	SAME AS 11 O'CLOCK
36°N	3 FISTS (30° ALT.)	2¼ FISTS (23° ALT.)	SAME AS 11 O'CLOCK
40°N	2½ FISTS (27° ALT.)	2 FISTS (20° ALT.)	SAME AS 11 O'CLOCK
44°N	2¼ FISTS (23° ALT.)	1½ FISTS (17° ALT.)	SAME AS 11 O'CLOCK
48°N	2 FISTS (20° ALT.)	1½ FISTS (14° ALT.)	SAME AS 11 O'CLOCK

Sight over top of fists at true south and 30° east and west (with adjustments in fist height) to determine shading effects. Any object above your fists will cast a shadow on the collectors; and anything below your fists will be of no concern.

Several "solar locators" are also commercially available (see Appendix C).

Other Factors to Consider

Collectors should be placed near (or slightly below) the mid-line of pitched roofs for best appearance. Location close to the ridge exposes the collector array to increased wind loading and heat losses. Collectors near the eaves can cause ice dams, which back up over the array. Water behind ice dams can be drawn under the shingles by capillary action.

Check to see if glare from the collector array will annoy neighbors or cause traffic hazards (particularly with ground-mounted collectors). A matte finish glazing material will help alleviate this problem. Collector boxes should be dark anodized if it develops that bare aluminum boxes create a reflection problem.

If the back of the collectors is visible, an enclosure may be desirable to improve appearance, reduce heat losses, and protect the collector array from wind loading.

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*See No Heat, No Rent: An Urban and Energy Conservation Manual. Energy Task Force, 519 East 11th Street, New York, NY 10009.

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ROOF- AND GROUND-MOUNTING PROCEDURES

This chapter takes you step-by-step through proper procedures for roof-mounting collectors, for making the necessary penetrations of the roof surface, and for ground-mounting collectors.

Hoisting Roof-Mounted Collectors

A typical collector weighs between 75 and 200 pounds. The careful installer should plan well in advance how to hoist the collectors to the roof.

There are a number of load lifting devices that you could choose to handle this job, such as a bucket truck, cherry picker, crane, fork lift, or Hyster®. A simpler device is a roof hoist which may be temporarily mounted on the roof (see Appendix C).

Manually lifting the collectors is possible, but it will require at least two men. One method is to use two parallel ladders with two men walking one collector up at a time. If the collector is outfitted with flanges, temporary handles may be attached (Figure 2.1).

The so-called "Push and Pull" method uses one ladder as a steep inclined plane. A rope is attached to one end of a collector. A man on the roof hoists the collector while another lifts and guides it up the ladder to prevent it from swinging out of control (Figure 2.2).

Precautions for Working on Roofs

Plan mounting procedures carefully to minimize the number of trips over the roof. Walk carefully on gravel roofs. They are more fragile than they appear, and the source of a leak in a gravel roof is not easy to locate. Lay down planks or plywood in heavy traffic areas.

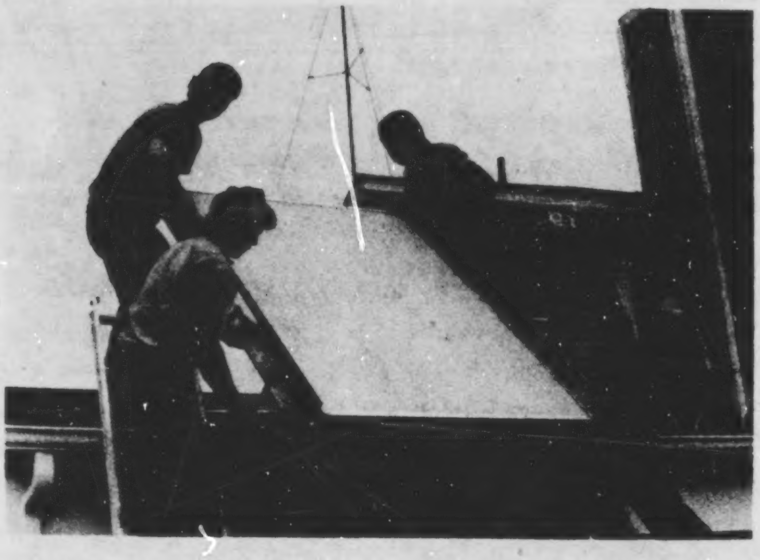

FIGURE 2.1: PARALLEL LADDER METHOD

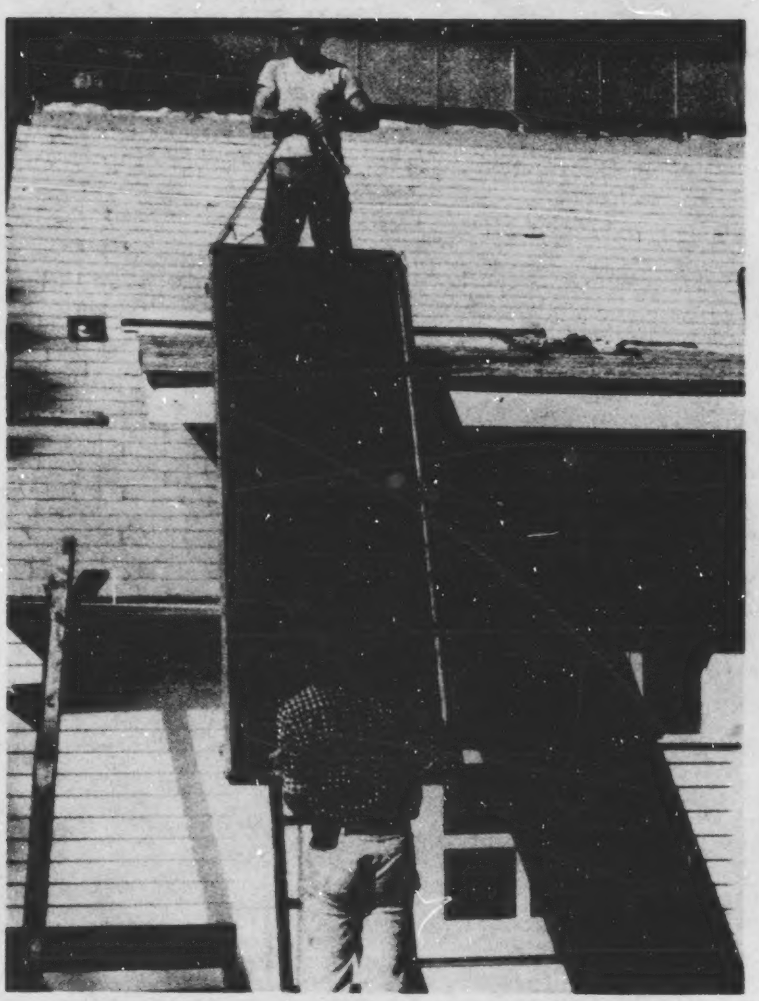

FIGURE 2.2: PUSH/PULL METHOD

Shake and clay tile roofs are very brittle. Be very careful walking and don't drop tools.

Specially designed roofer's shoes are recommended on asphalt shingle roofs. Shoes with heavy lug soles should be avoided because they can damage shingles, especially in warm weather.

Wind Loads

According to HUD's IMPS, the mounting structure should be built to withstand winds of at least 100 mph (which impose a wind load of 40 pounds per square foot on a vertical surface or an average of 25 pounds per square foot on a tilted roof). Flat-plate collectors mounted flush with the roof surface should be constructed to withstand the same wind loads.

When mounted on racks, the collector array becomes more vulnerable to wind gusts as the angle of the mount increases. Collectors can be uplifted by wind striking the undersides. This wind load, which is in addition to the equivalent roof-area wind loads, should be determined according to accepted engineering procedures. Cross-brace all mounting racks (Figure 2.3).

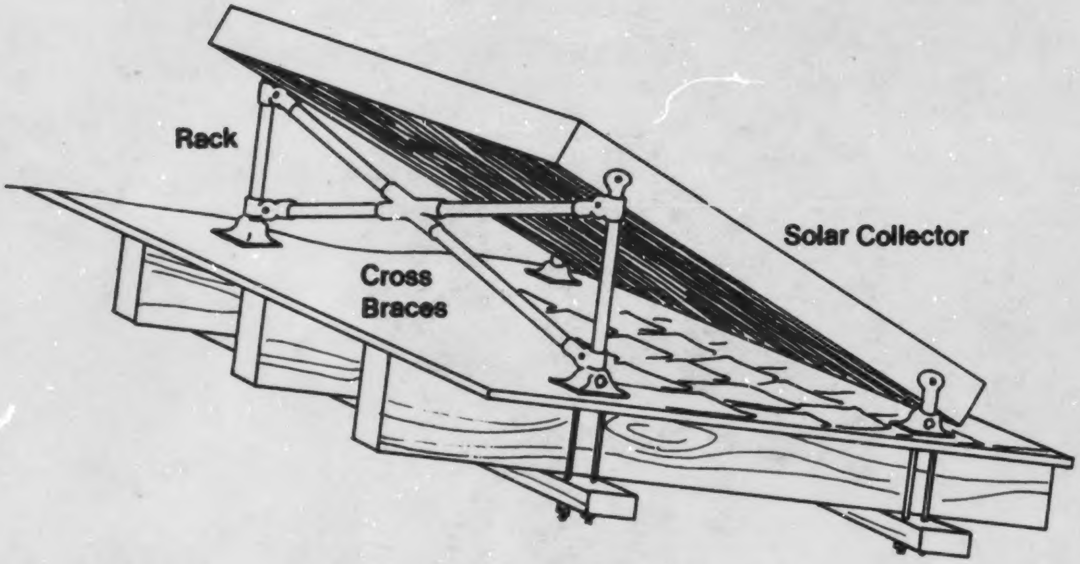

FIGURE 2.3: CROSS BRACING RACK

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Snow Loads

Collectors mounted flush on a roof should be designed to support the snow loads that occur on the roof area they cover. The collector array may be tilted 5° to 10° greater than the latitude to expedite snow sliding, with only a minimum loss in efficiency. Precautions must be taken so that snow slides are not a hazard to pedestrians.

The roof structure should be free of objects that could impede snow sliding and the collectors should be raised high enough to prevent snow build-up over them. Collectors mounted on elevated racks or in sawtooth patterns may create snow drifting on the roof in addition to normal snow loads. This additional build-up must be considered in the design loads (Figure 2.4).

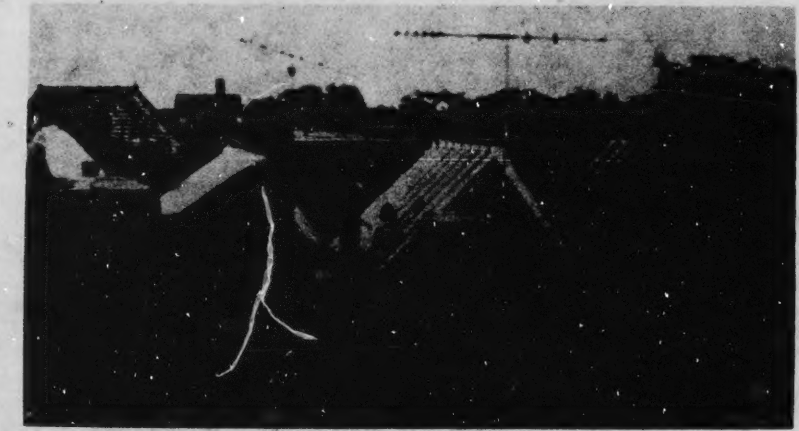

FIGURE 2.4: SAWTOOTH PATTERN

Check Roof Conditions

See that the roof surface is in good repair before mounting collectors. If there is a need for reshingling or other repair work, think seriously about doing the work before mounting the collectors. Keep future roof repair and maintenance in mind when planning collector mounts. Easily removable collectors will make such work easier. Do not mount collectors on warped or cracked wood shingle roofs.

Positioning Collectors

Be sure the collector array is parallel with the ridge of the roof. Measure distance from the top of the collector array to the ridge line at each end and check with a bubble level. A chalk line makes a useful guide. Slope the array toward the inlet to facilitate drainage at the minimum rate of ⅛-inch per foot. Allow at least ¼-inch spacing between collectors for expansion and contraction which could loosen the mounting (Figure 2.5).

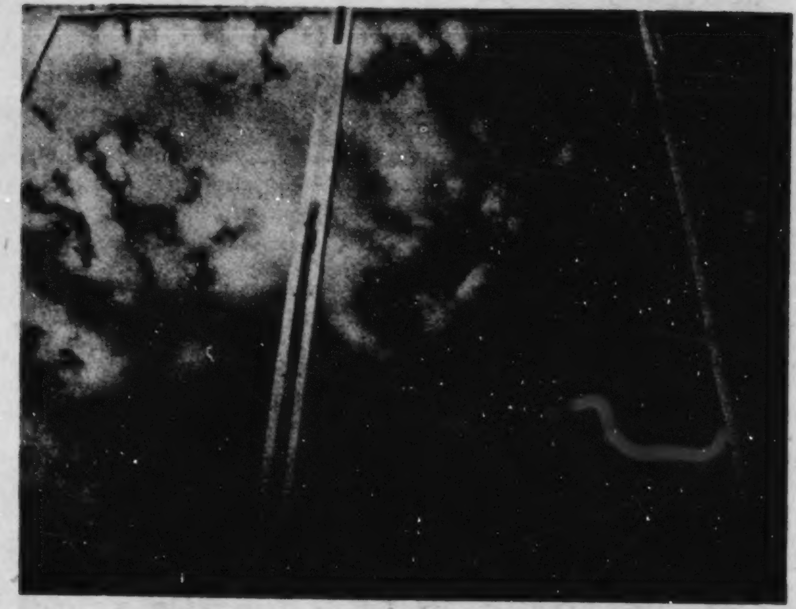

FIGURE 2.5: LEAVE SPACE BETWEEN COLLECTORS

Collectors with weep holes should be mounted with weep holes at the bottom. They allow moisture to escape because condensation can damage some absorber surfaces. Holes should be loosely blocked with glass fiber that will prevent entry of dirt or insects but will allow a flow of air.

Installing Spacers

On retrofit installations, collectors should be raised at least 1½ inches above the roof to avoid damage to shingles. Without that space, moisture buildup could cause growth of fungus, mold, and mildew. Ice dams could also form and draw water under shingles by capillary action. These factors contribute to roof surface deterioration.

Spacer blocks of rot-resistant wood (such as redwood or cedar) should be used between collector and roof surface. Other types of wood can be used if pressure-treated with a preservative such a creosote or pentachlorophenol. Note that some preservatives may dissolve asphalt roofing materials and should not be in direct contact with them. Blocks of Plexiglass® or other UV-resistant plastic also can be used. A silicone sealant or fibrous roofing cement should be applied liberally between spacer and roof surface, or use a neoprene pad (Figure 2.6).

Instead of a block spacer, a mounting angle or clip can be used. It should be made of a metal compatible with the metal of the collec-

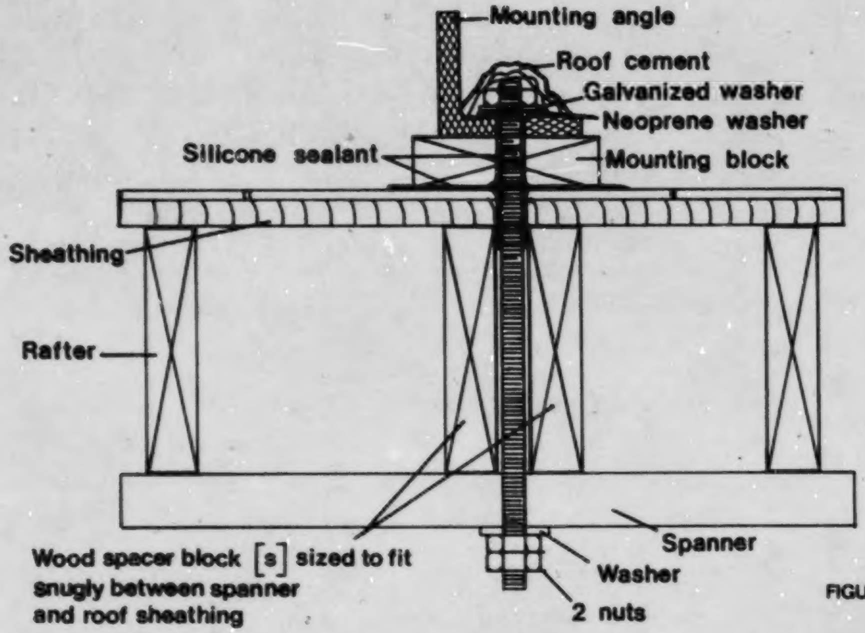
Mounting angle
Roof cement
Galvanized washer
Neoprene washer
Silicone sealant
Mounting block
Sheathing
Rafter
Wood spacer block [s] sized to fit snugly between spanner and roof sheathing
Spanner
Washer
2 nuts

FIGURE 2.6: SPACER BLOCK WITH SPANNER MOUNT

tor box. Fasten it directly to the collector box or flange and bolt it to the roof with a compatible metal fastener.

Spanner Mounting

A spanner mounting is recommended if the attic is accessible, because the uplift force of wind on the collector array will be evenly distributed to the roof framing members. Screw or nail 2" x 4" spanners directly to the rafters inside the attic, perpendicular to the rafters (Figure 2.7). At least two, and preferably three, spanners should be used. Pre-drill holes through the roof and mount spacers large enough to accept the thru-bolts. Be careful not to split the spacers. It may be easier to drill holes and insert thru-bolts before securing spanners to assure proper alignment of holes.

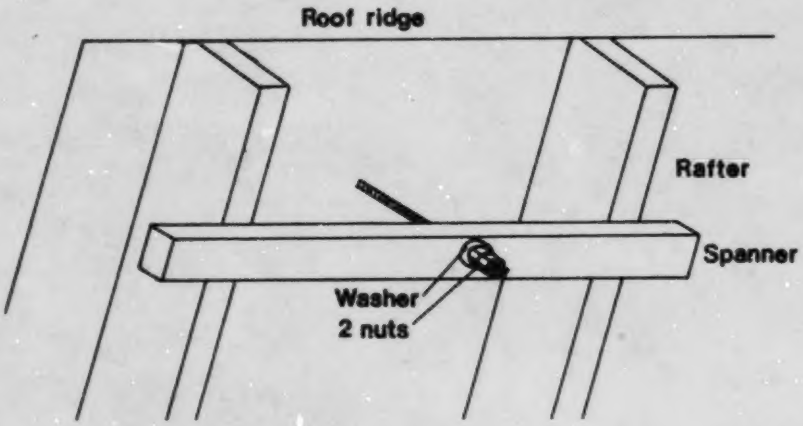
Roof ridge
Rafter
Spanner
Washer
2 nuts

FIGURE 2.7: SPANNER MOUNTING

Thru-bolts or threaded rods should be at least ⅜-inch in diameter. Two nuts and large-diameter (fender) washers are recommended on both ends of the threaded rod. Silicone sealant should be applied generously to holes and between washers and mounting blocks. Use neoprene washers in conjunction with metal washers to minimize risks of leakage.

CAUTION! Be sure that the holes contain enough sealant to prevent leakage. Sealant should ooze liberally from around bolt heads when they are tightened down (Figure 2.8).

FIGURE 2.8: SEALANT

After bolt heads are tightened, apply more sealant over the heads and mounting block or clip assembly. If roof cement is used rather than silicone, the fibrous type is recommended because the weatherproof seal remains intact over repeated expansions and contractions.

Spanner Mounting in a Concealed Attic

Because an installation should last many years if properly installed, it may be worthwhile to cut sheetrock to expose rafters and then repair it. Nail wood blocks to inside of the rafters at least 3 inches short of the ceiling edge. Fasten the spanners on these blocks and bolt. Use threaded thru-bolts as described above, seal, and bolt. Replace gypsum board to cover installation (Figure 2.9).

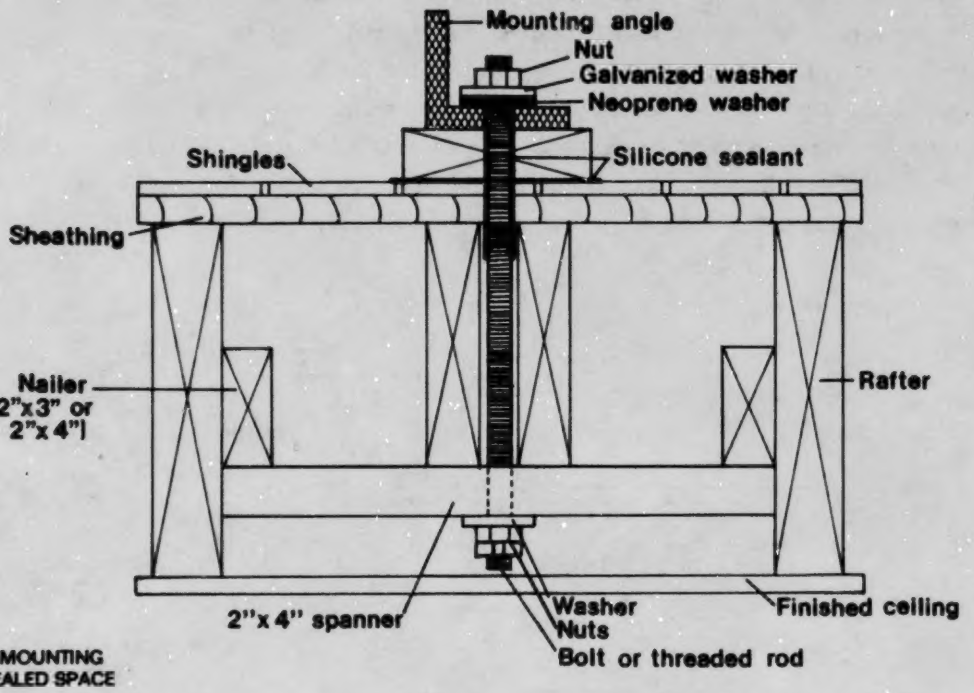
Mounting angle
Nut
Galvanized washer
Neoprene washer
Shingles
Silicone sealant
Sheathing
Nailer
[2"x3" or 2"x 4"]
Rafter
2"x 4" spanner
Washer
Nuts
Bolt or threaded rod
Finished ceiling

FIGURE 2.9: SPANNER MOUNTING IN CONCEALED SPACE

Lag Bolt Mounting

When the attic is completely inaccessible, collectors or the mounting racks can be lag bolted directly to the roof from outside.

CAUTION!

Lags must be fastened to rafters or trusses rather than to sheathing so wind cannot pull them free.

Rafters or trusses can be located by tapping the roof with a hammer. The more solid sound indicates a framing member. Rafters or trusses generally will be on 16" or 24" centers (Figure 2.10).

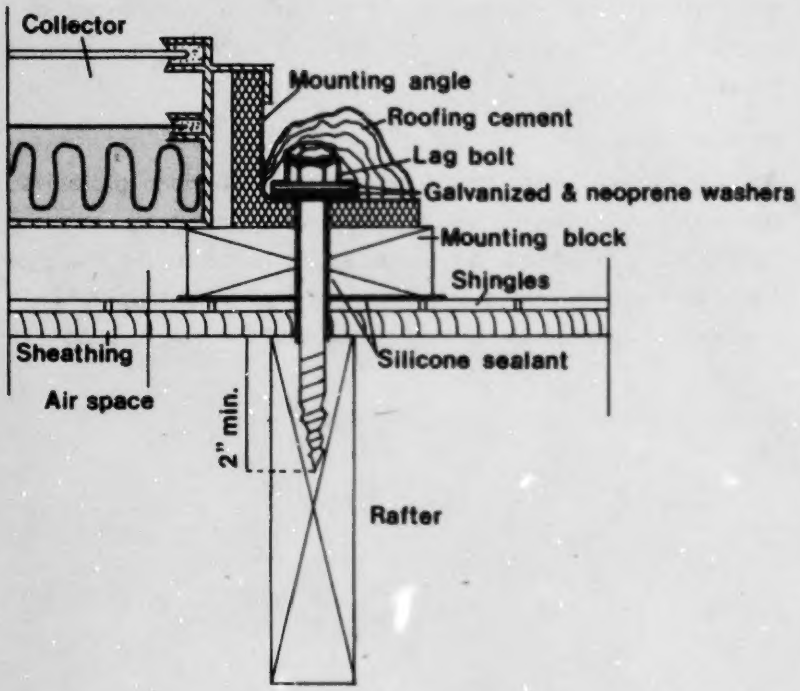
Collector
Mounting angle
Roofing cement
Lag bolt
Galvanized & neoprene washers
Mounting block
Shingles
Sheathing
Silicone sealant
Air space
2" min.
Rafter

FIGURE 2.10: LAG BOLT MOUNTING

Drill holes through the roof several sizes smaller than the bolt to assure a tight fit. The lag bolt should penetrate the rafters at least two inches. Insert the lag bolt through a metal washer and then through a neoprene washer before going through the collector flange and mounting block. Be sure to apply a liberal quantity of sealant to the holes and between mounting blocks, washers, and the roof surface before tightening down lag bolts. After mounting, apply more sealant over the entire assembly.

Rack Mounting

Collectors can be mounted on racks or stand-offs to achieve the optimum tilt angle. If the holes or clips on the collectors do not line up with rafters or trusses, you may mount the collectors on a rack, then fasten the rack to the framing members properly.

The rail should be at least 12 gauge and about 1½" by 1½" in dimension; slotted angle rail, normally used to fabricate warehouse shelving, is readily available and can be cut to any length and bolted together. The collectors should be bolted to the rail framework. Take care to prevent galvanic corrosion. The framework is lag-bolted or spanner-mounted to the roof, and roof penetrations carefully sealed. Asphalt tape may be used between the rack and the roof.

Pipe Mounting

Another collector mounting approach uses one-inch galvanized pipe and fittings used in awnings, or a pipe and fitting system called Speed Rail®, which can be secured with set screws. The pipe framework can be welded or bolted to ⅜-inch steel support plates that are corrosion protected and fastened to the roof (Figure 2.11).

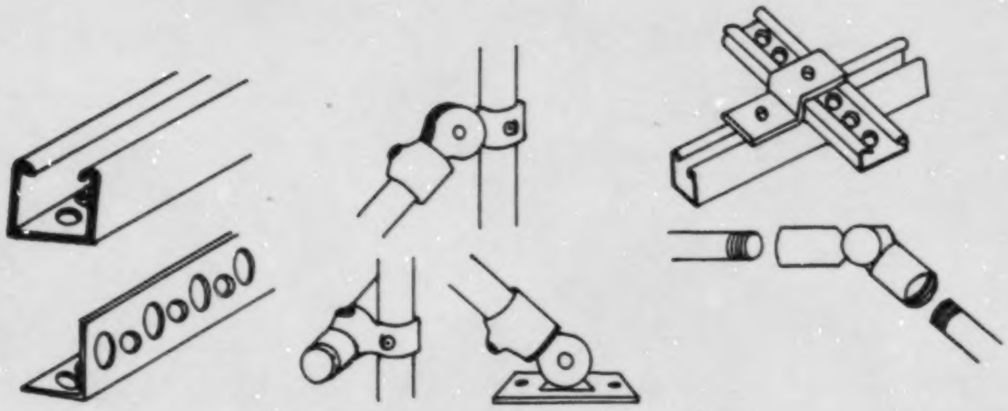

FIGURE 2.11: RACK MOUNTING MATERIALS

CAUTION! All racks must be constructed to withstand anticipated extreme weather conditions. The bottom of the collector array must be at least 1½ inches off the roof to allow water, snow, ice, and other debris to pass under. All racks must be diagonally cross-braced.

Mounting Techniques for New Construction

Experience has shown that for new roofs with the correct pitch, the best method for mounting collectors is to place the collectors directly on the felt paper. Flashing should extend over the collector flange onto the felt paper. At the top and sides of the collectors, shingles should be applied over the flashing. Flashing should be over the shingles at the bottom. A layer of sealant should be applied between the collector and the roof surface. The collectors can be attached according to the lag-bolt or spanner method as discussed previously, but without using spacer blocks (Figure 2.12).

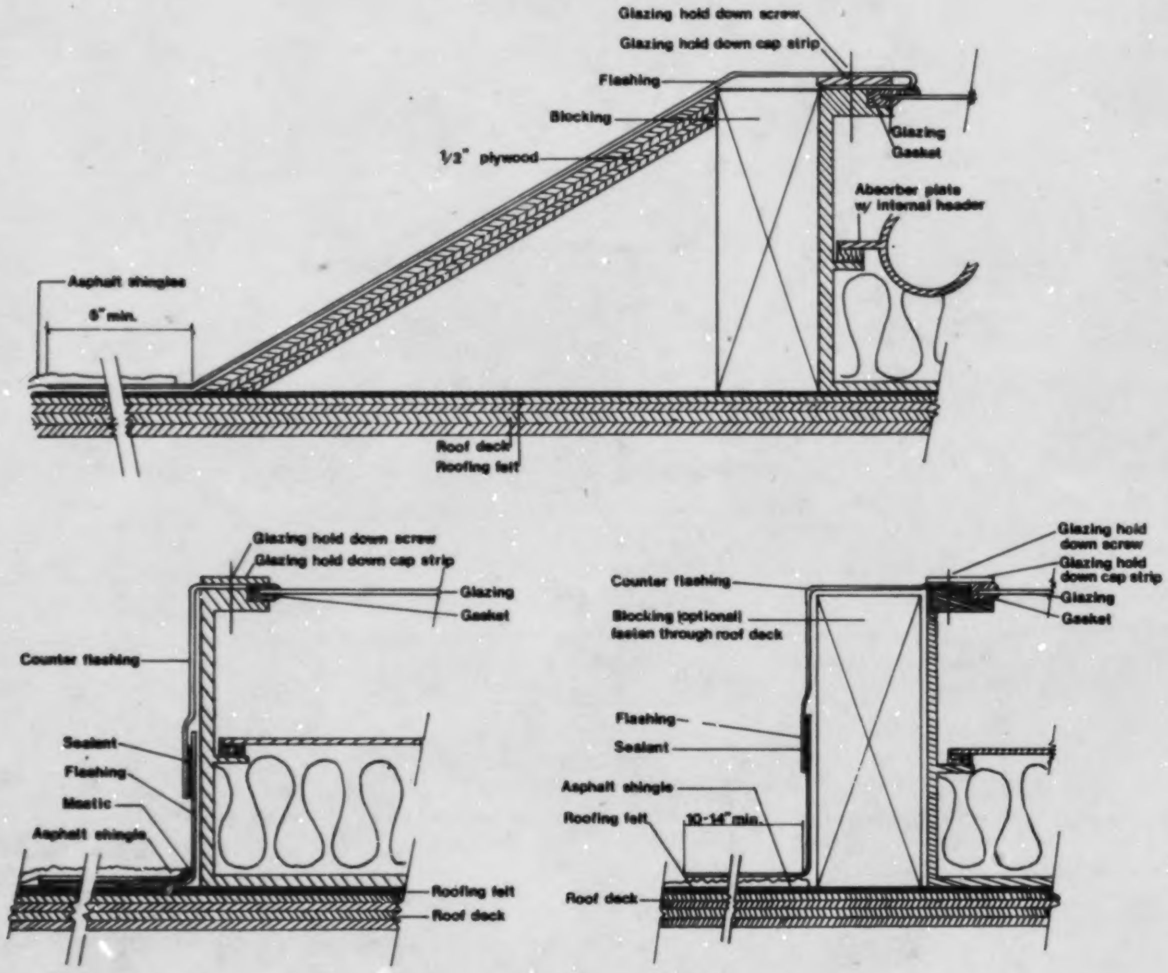
Glazing hold down screw
Glazing hold down cap strip
Flashing
Blocking
1/2" plywood
Glazing
Gasket
Absorber plate w/ internal header
Asphalt shingles
6" min.
Roof deck
Roofing felt
Glazing hold down screw
Glazing hold down cap strip
Glazing
Gasket
Counter flashing
Sealant
Flashing
Mastic
Asphalt shingle
Roofing felt
Roof deck
Counter flashing
Blocking (optional) fasten through roof deck
Flashing
Sealant
Asphalt shingle
Roofing felt
10-14" min.
Roof deck
Glazing hold down screw
Glazing hold down cap strip
Glazing
Gasket

FIGURE 2.12: FLASHING INTO NEW ROOF: TOP, SIDE, AND BOTTOM VIEWS

Aluminum reacts with wood preservatives. **CAUTION!**

Mounting Techniques for Flat Roofs

On flat roofs, collectors can be mounted on uprights which are then fastened to the roof. The base of the upright is placed in a pitch container and both are simultaneously bolted onto the roof, by either the spanner or the lag bolt method (Figure 2.13). The container should have a lip to accept flashing, which is extended down onto the roof surface. The container is then filled with pitch or roofing cement. Pitch pots require frequent inspection and do not have lasting watertight qualities.

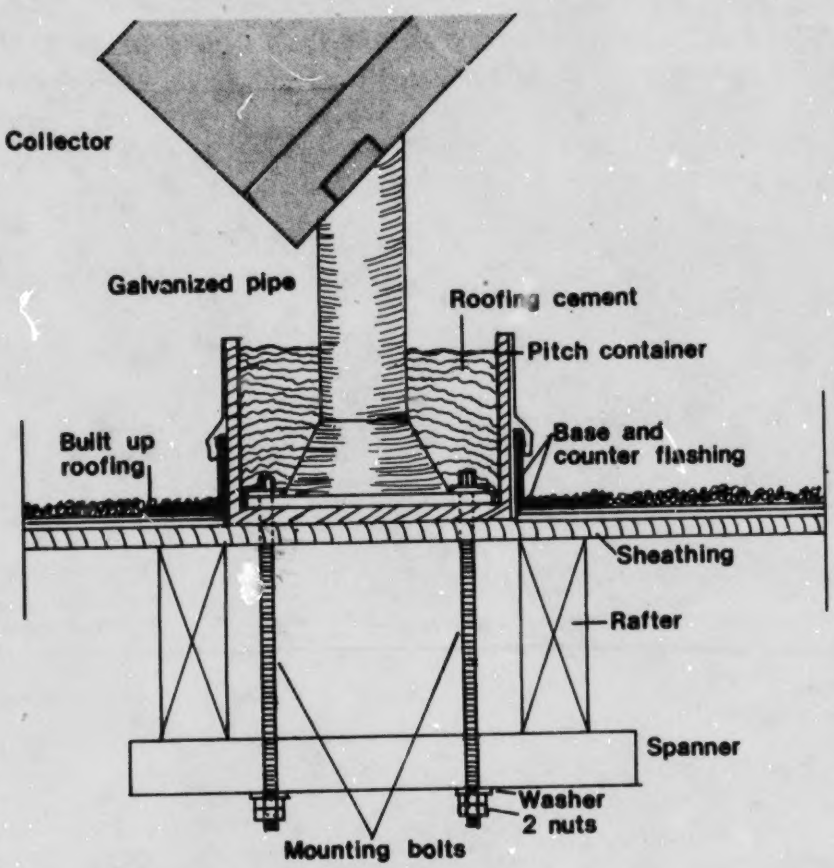
Collector
Galvanized pipe
Roofing cement
Pitch container
Built up roofing
Base and counter flashing
Sheathing
Rafter
Spanner
Washer
2 nuts
Mounting bolts

FIGURE 2.13: PITCH POT METHOD

The National Roofing Contractors Association recommends use of curb mounts. A curb mount requires building up the roof surface with framing members to act as an equipment support. The curb is flashed into the roof surface and covered with a sheet metal hood. The collector support is bolted through the hood and flashing into the curb (Figure 2.14). The NRCA recommends that curbs on flat roofs not span the whole roof so that water pockets don't develop.

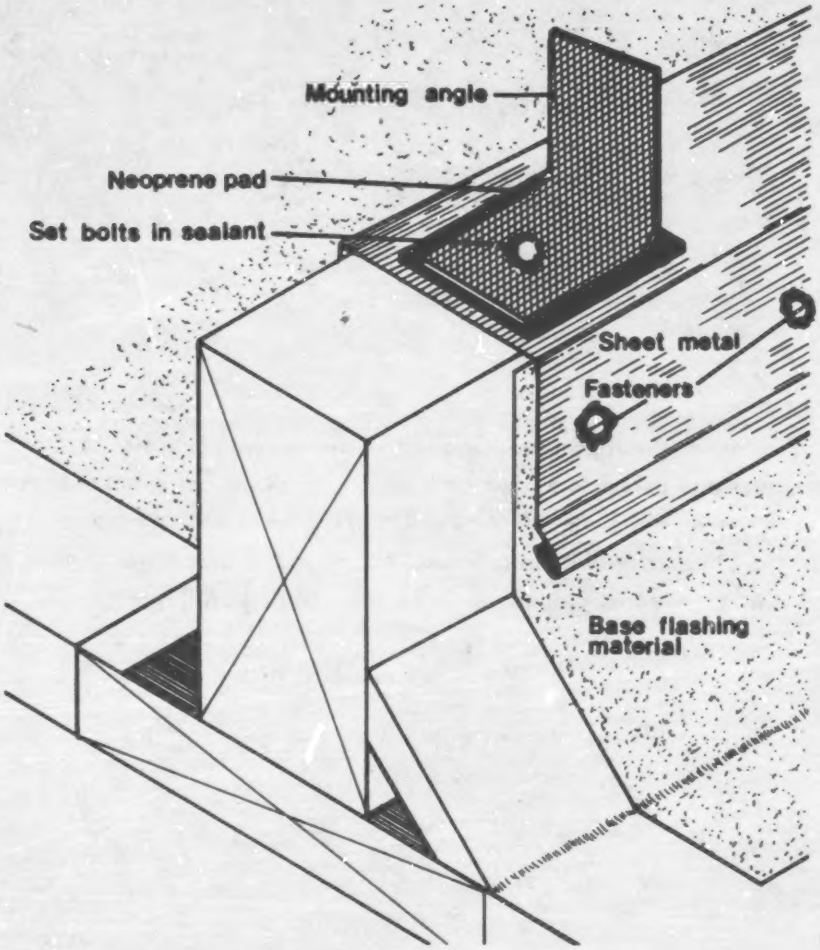

FIGURE 2.14: CURB MOUNT METHOD

ROOF PENETRATION FOR PIPES

It usually will be necessary to run pipes as well as fasteners through the roof surface. Keep the number of penetrations to a minimum. Pipes are flashed using the same methods as for vent pipes or soil stacks. The most common way is to use a roof flange (Figure 2.15).

Roof flanges are readily obtained from roofing or building supply yards with the most common sizes ranging between 1¼ and 4 inches. They are available in galvanized steel, aluminum, neoprene, or copper, and some have neoprene collars. The neoprene collar flanges do not require a sealant where the pipe passes through, and the collars are adjustable to any roof pitch.

Select a roof flange that will make a tight fit over the pipe. Remember that pipe insulation also must pass through the roof. Coat the bottom of the flange with sealant before fastening to the roof

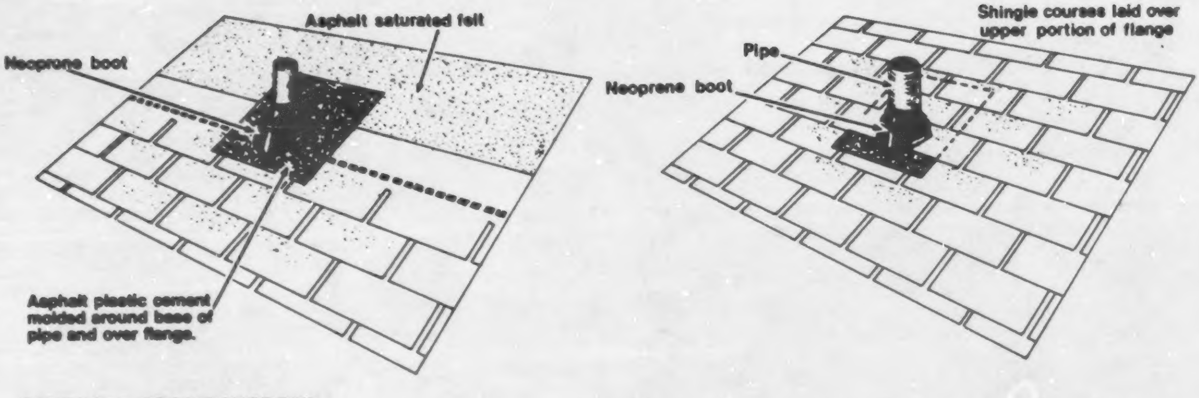
Asphalt saturated felt
Neoprene boot
Asphalt plastic cement molded around base of pipe and over flange.
Shingle courses laid over upper portion of flange
Pipe
Neoprene boot

FIGURE 2.15: ROOF FLANGE FOR PIPE PENETRATION

surface. The top of the flange must be completely under the shingles and the bottom over the shingles. Apply more sealant between shingles and flange. If the insulation does not have a rigid casing, an alternative method is to insulate up to the penetration and use reducers and a plastic nipple for the penetration (Figure 2.16).

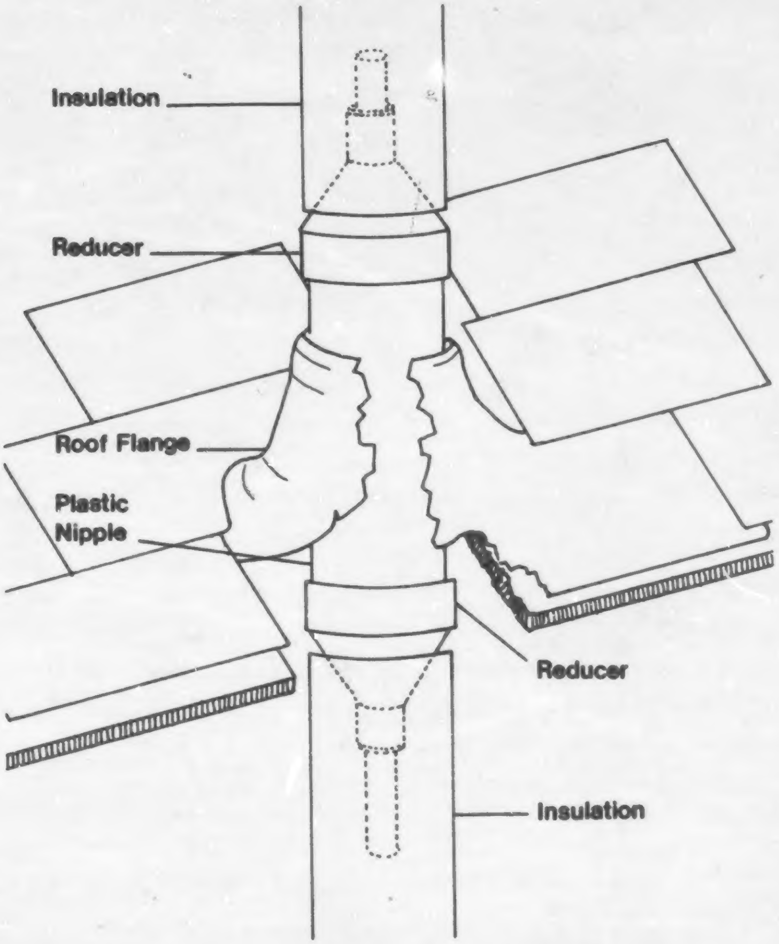
Insulation
Reducer
Roof Flange
Plastic Nipple
Reducer
Insulation

FIGURE 2.16: ALTERNATE ROOF PENETRATION

GROUND MOUNTINGS

If there is too little roof space or the roof faces the wrong direction, collectors can be ground-mounted. Ground mounts make installation easier by eliminating roof work, simplifying maintenance, and in most cases, shortening the run from collectors to storage.

Zoning

Before starting construction of a ground-mounted collector array, check local zoning ordinances. The ground-mounted unit will have to conform with local requirements for setback, density, classification of structure (will it be considered a new building?) and aesthetic requirements. Aesthetics are particularly important in some localities, which may even require that the supporting framework be enclosed and finished off to resemble the house.

Footings

Collectors are mounted on a rack or frame that must be securely attached to footings extending below the local frost line. There should be at least four pier footings, 8″ x 8″ square or in diameter. Footing holes should be dug below the frost line and the bottoms filled with an inch or two of dry, washed pebbles. The footings should be poured with a frame member or a threaded rod protruding from the concrete (Figure 2.17).

If the frame is embedded, make a temporary jig so that the rack holds shape while the concrete sets. If the frame member is wood, it must be treated to slow deterioration. If you are using a threaded rod, it must be at least ⅜-inch in diameter. Instead of pouring four footings, you might want to pour two parallel walls (Figure 2.18).

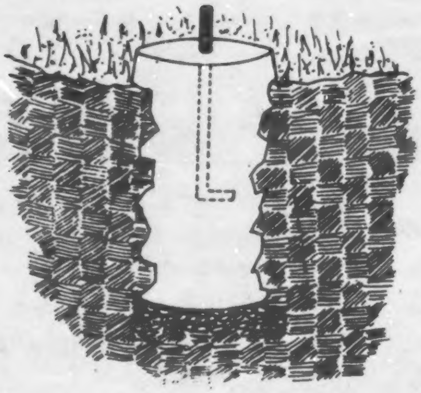

FIGURE 2.17: PIER FOOTING

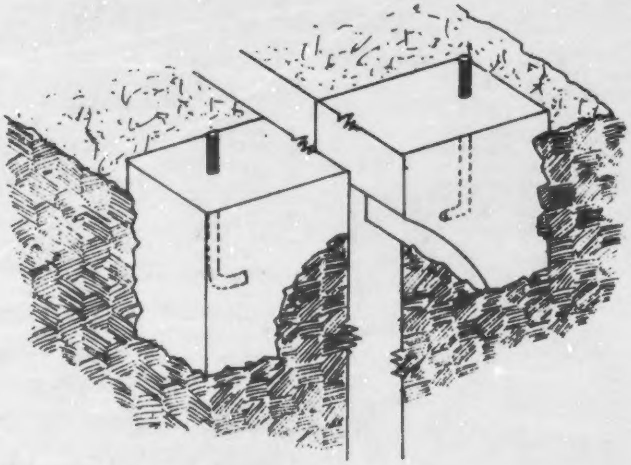

FIGURE 2.18: WALL FOOTING

Ground-Mounting Frames

The collector frame can be made from several materials: galvanized steel pipe, aluminum and steel angle iron, or even wood.

Galvanized steel pipe and fittings are readily available. If the collector boxes are aluminum, keep the steel and aluminum from touching each other directly to prevent galvanic corrosion.

Slotted steel angle iron of at least 12 gauge and about 1½ by 1½ inches can be easily cut to any length and bolted together. Again careful attention must be paid to corrosion control (see below).

Aluminum angle extrusions will be lighter than steel angle iron and more corrosion resistant, as well as galvanically compatible with aluminum collector boxes. However, you can expect aluminum standard shapes to be more expensive than steel.

Wooden collector frames must be made of redwood, cedar, or other wood treated to resist rotting, weathering, and insects.

Framework Requirements

In addition to proper elevation and orientation, the bottom edge of the collectors must be a minimum of 18 inches off the ground to prevent mud splashing and snow drifting up to cover the bottom of the panels. It is wise to attach a small gutter below the collectors to prevent excessive erosion of the soil directly in front of the collector array. A pebble bed in front of the collectors will also help prevent erosion.

Remember that the framework must be cross-braced and built to withstand the dead load of the collectors, live snow loads, and wind loads up to 100 MPH (see Wind Loads and Snow Loads above). The collector array must not be subjected to warping that can result from soil freezing. This can be prevented by bracing with a continuous strong member around the base of the framework or by building the footings as two walls.

Piping

The run to and from storage should be as short as possible, with a minimum amount of bends and elbows. Pipes must be insulated and weatherproofed. If the system is a drainback system, the bottom of the collector array must be a minimum of 2 feet above the water level in the storage tank. In both draining and closed-loop antifreeze systems, all pipes must be pitched to provide drainage. Provide air vents at all high points.

CORROSION PROTECTION

Both roof-mounted and ground-mounted collector arrays and mounting hardware (bolts, screws, washers, angles) must be carefully protected from corrosion. Steel mounting hardware in contact with aluminum and copper piping in contact with aluminum hardware are both examples of high corrosion-potential combinations. Cadmium-plated or hot-dipped galvanized bolts can be used to mount collectors on racks. If the coating is scratched, prime with zinc chromate paint or special zinc-rich coating. The exposed edges of galvanized steel angle iron should be similarly treated.

Dissimilar metals can be separated by washers made of fluorocarbon polymer (such as Teflon[R]), phenolic (such as Bakelite[R]), or neoprene rubber. When a bolt passes through two dissimilar metals, the inert washer should have an insulating sleeve (Figure 2.19). Most collector manufacturers supply mounting hardware specifically designed for their equipment. Follow instructions carefully, and be sure to cover all holes and mounting assemblies with a high-quality sealant.

Safety

Cover collectors with opaque material until the system is running to prevent heat build-up. Take care not to burn hands on collector boxes during sunny weather.

Ground-mounted collectors require somewhat more effort to protect the array from possible vandalism and to prevent injuries to the owner's family and visitors. Consider covering the collector array with a layer of chicken wire one foot above the glazing if it appears that vandalism is a possibility. Be sure that the glazing can still be easily cleaned. Check for sharp protruding nail points or angle iron edges. If children are apt to play in the vicinity of the array, suggest that the installation include fencing around the collectors to prevent burns or other accidents.

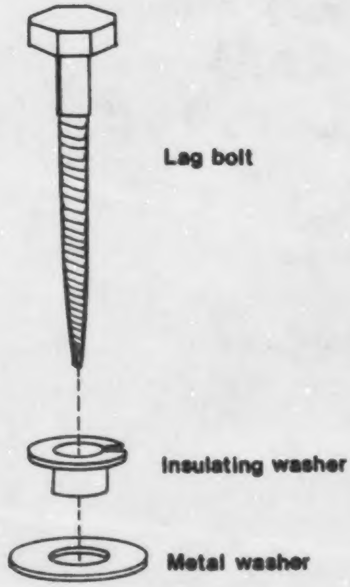

FIGURE 2.19: LAG BOLT AND INSULATING WASHER

TRANSFER FLUIDS, PIPING, AND DUCTWORK

Each heat transfer fluid has differing properties, such as viscosity, specific heat, freezing, boiling, and flash points, that will determine the size and design of many components (see Table 3.1).

Corrosion

The combination of dissimilar metals and any heat transfer fluid that conducts electricity to some extent will lead to galvanic corrosion when the more chemically active metals are attached. It can be avoided by:

1. Using an nonconductive heat transfer fluid, such as a silicone or hydrocarbon oil.
2. Using one metal throughout the whole system. If the metal is copper and the transfer fluid is water, there is no need to add corrosion inhibitors.
3. Using an air-to-water system.

Water/glycol antifreeze mixtures require an added inhibitor because glycol breakdown products include acids. Aluminum in the system will also require an inhibitor. Most commercially available transfer fluids are sold with inhibitors already added, but some will require the installer to formulate the proper mixture. Follow the manufacturer's directions carefully. Most of the common inhibitors carried in solution are sacrificial (the inhibitor is attacked, rather than the plumbing) and, therefore, require the installer or the owner to follow a regular maintenance schedule to replace the transfer fluid.

Be sure to flush the system out completely prior to filling to remove solder flux, metal filings, etc. Direct connections between dissimilar metals must be avoided. The use of insulating washers (plastic, rubber) or silicone hoses between dissimilar metals will reduce galvanic reactions at that point.

TABLE 3.1 TRANSFER FLUIDS

MEDIUM	SPECIFIC GRAVITY	VISCOSITY[1] CENTIPOISE	HEAT CAPACITY (BTU/lb.°F)	FREEZING POINT, °F
Water	1.000	0.5 to 0.9	1.00	+32
50 wt. % Water-ethylene glycol	1.05	1.2 to 4.4	.83	−33
50 wt. % Water-propylene glycol	1.02	1.4 to 7.0	.85	−28
Paraffinic Oils	.82	12 to 30	.51	+15
Aromatic Oils	.85	0.6 to 0.8	.45	−100
Silicone Oils	.94	10 to 20	.38	−120

[1] Because viscosity is sensitive to temperature, values are given for a temperature range of approximately 80°F to 140°F.

In solar collector systems, as in any system involving circulating liquids, it is not sufficient to use a dielectric fitting to separate dissimilar metals from direct contact. Copper ions can be carried by the fluid and deposited on another metal, causing pitting. Although complex systems of corrosion protection are available for mixed-metal systems, the best solution is simply not to mix metals.

Thoroughly flushing out a system before filling with a transfer fluid helps to prevent galvanic corrosion. Filings of one metal lodged in an absorber plate or heat exchanger coil of a dissimilar metal can cause galvanic corrosion.

Water

Remember that water combined with dissimilar metals can cause galvanic corrosion. The experienced installer probably will be aware of the local pH and mineral hardness problems, because of the effects of hard water on conventional heat water systems. Even if local water is not used in the collector loop, mineral deposits in the storage tank on the outside of the heat exchanger loops will lower system efficiency. If local water conditions are extreme, chemical additives or electro-magnetic devices should be considered to protect the solar DHW system. Whatever the local water conditions, distilled or deionized water is recommended for drainback systems with a heat exchanger. A qualified water treatment engineer should prescribe a treatment to make problem water safer for plumbing materials.

Drainback systems must be designed so that they drain completely and automatically under freezing conditions. Pumps for all systems using water as a heat transfer fluid should be either bronze or stainless steel.

In a closed loop system, a non-acidic flux should be used to prevent chloride build-up which can cause pitting.

Glycol/Water Antifreeze Solutions

WARNING!

Care must be taken that the proper glycol mixture and heat exchanger have been specified. Ethylene glycol/water mixtures are TOXIC and require a double-walled heat exchanger. Food-grade propylene glycol U.S.P./water mixtures—when certified nontoxic—can be used with a single-walled heat exchanger if no toxic dyes or inhibitors have been added to the mixture. However, inhibitors which are Generally Recommended As Safe (GRAS) by the FDA, such as dipotassium hydrogen phosphate, should be added to U.S.P. propylene glycol to maintain the proper pH. Many manufacturers already do this.

Water/glycol solutions should be at least 20 percent glycol. The margin of freeze protection should be 10°F. below the historic low of the region. A 50/50 solution is good down to −32°F., and maximum freeze protection is achieved with a 40/60 water/glycol mixture.

Water/Glycol Installation, Safety, and Maintenance

Do not use glycol solutions with zinc galvanized plumbing because the required corrosion inhibitors react with zinc. Glycols may damage certain materials such as the butyl rubber membranes in certain types of expansion tanks. If water/glycol mixtures are exposed to air through an air vent or a vacuum breaker and high temperatures, acids will form. If these conditions occur, the pH, inhibitor strength, and solution concentration of the water/glycol must be checked, and the solution replaced if necessary. Periodic checks and replacement will be required in any case.

Remember that glycol solutions will leak through joints where water would not. Good seals and Teflon[R] tape should be used. Glycols should be dyed with nontoxic food-coloring dye, if not bought that way, to help identify leaks. Make-up supply, in case of leaks, should not be added automatically from the city water supply, as this will reduce the glycol concentration. Depending on local codes, water/glycol solution should be drained into dry wells or waste drains (sanitary sewers, not storm sewers).

Paraffinic or Mineral Oils

Paraffinic or mineral oils are petroleum-based heat transfer fluids. Their useful temperature range between freezing and boiling is greater than that of water, and they are nonconducting. These oils have a higher viscosity than water and may require a larger pump. Because they will break down into tarry materials under prolonged exposure to heat, periodic replacement is necessary.

WARNING!

Paraffin oils are considered TOXIC and require a double-walled heat exchanger.

Silicones

Silicone heat transfer fluids are quite inert and will cause neither galvanic corrosion nor degradation of roofing materials. They also have a very high flash point. These fluids have high viscosities and low specific heats compared to water; therefore, large pumps and a flow rate of about 2½ times that used for water are required. Silicones are incompatible with expansion tanks fitted with neoprene or butyl rubber diaphragms.

Silicone fluids will leak readily through piping flaws that will retain water. Even sweat-soldered joints in copper pipe will leak if not properly soldered. A manufacturer-recommended pipe dope should be used at all threaded joints. Check all manufacturer-supplied connections for proper sealant.

Avoid using silicone tubing or silicone sealants in the system. EPDM rubber or Viton^R is preferred. Use seal-less (canned) pumps with magnetic drives. Use non-acidic flux when soldering to prevent contamination of the neutral heat transfer fluid.

Aromatic Oils

Aromatic oils have lower viscosities than paraffins; this allows smaller pumps to be used. They also have lower flash points, which make them less safe to use.

Aromatics will dissolve roofing tar and most elastomer seals. Viton^R seals should be used in pumps whenever paraffinic or aromatic hydrocarbon oils are used.

Water/Glycerine Solutions

A 40/60 solution of water/glycerine (glycerol) is nontoxic and does not require a heat exchanger with double separation. Water/glycerine solutions have higher viscosities than water/glycol solutions and, therefore, may require a larger pump. However, glycerine solutions are subject to biological contamination and may become corrosive if overheated.

Air

Air may also be used to transfer heat from collectors to the domestic hot water supply. The advantages are it cannot freeze or boil, and it is noncorrosive and free. Disadvantages for the installer are that ducts are difficult to make airtight and that leaks are difficult to detect. Leakage will further reduce the efficiency of an air system which already has a much lower heat-carrying capacity than an equal volume of a liquid.

RECOMMENDED TYPES OF PLUMBING

The most favored plumbing for solar DHW systems is sweat-soldered, L-type copper tubing. M-type copper is also acceptable if it is allowed by local building codes.

All joints in copper tubing in and near the collector array should be soldered with 95-5 tin-antimony solder to avoid joint failure at stagnation temperature. While 95-5 could be used throughout the rest of the system and should be used in a silicone system, 50/50 tin-lead solder can be freely substituted in those parts of the system that will not be subjected to the extremes of stagnation temperature. Remember that silicones and glycols demand well-soldered joints.

Although soldered joints are preferred, threaded joints may be made with a good quality joint compound and/or Teflon^{R} tape. Examples of quality joint compounds are: Loctite^{R} pipe dope with Teflon^{R} (Part No. 529), Crane^{R} Je-30 pipe thread sealer with Teflon^{R}, Rector^{R} Seal No. 5, and Dow Corning^{R} 730 Fluorosilicone rubber sealant, and their equivalents.

CAUTION! If the heat transfer fluid is a silicone or a water/glycol solution, standard pipe dope WILL NOT prevent leakage.

If concentrating or evacuated-tube collectors are to be used, silver solder or brazing alloys are required throughout the system because of the high temperatures encountered. Some building codes demand the use of silver solder, silver-bearing filler metals, or other brazing alloys for all concealed pipe runs in ditches and walls. Check your local codes before proceeding.

Plastic Pipe

Do not use PVC for hot water applications. CPVC will sag at about 160°F. if not adequately supported, thereby preventing draining of draindown systems, making flushing out of non-draindown systems more difficult, and preventing air bubbles from venting properly. Polybutylene pipe will begin to sag at about 200°F. In general, use extra care when using plastic pipe.

Galvanized Threaded Pipe

Conventional galvanized threaded pipe may be used if already installed in the existing DHW system. All threaded joints should be thoroughly pipe doped.

Silicone Coupling Hoses

Silicone coupling hoses are sometimes recommended by the manufacturer for connecting collectors to the array manifold or to act as expansion joints in the hot water return circulation. Those hoses can also be used between plumbing of dissimilar metals to retard galvanic corrosion.

CAUTION!

Ordinary automobile radiator hoses should never be used, as they break down rapidly when exposed to the ultravoilet waves in sunlight.

Silicone hoses should be clamped with lined stainless steel hose clamps without the usual perforations. The rubber will extrude through the perforations.

Hanging and Anchoring Pipe

Pipe hung vertically should be anchored at the following intervals:

COPPER TUBING: one story or ten-foot intervals

THREADED PIPE: every other story

RIGID PLASTIC PIPE: half-story intervals.

Pipe hung horizontally should be supported at the following intervals:

COPPER TUBING: eight-foot intervals for drawn tube, six-foot for annealed tube

THREADED PIPE: twelve-foot intervals

RIGID PLASTIC PIPE: one-to-two-foot intervals

Pipe Runs

Long pipe runs increase heat losses, pressure drops, and installation costs and may require installing larger size pipe (see Appendix B).

Pipe chases from rooftop collectors should be run through closets and between wall partitions. If pipes must be routed through rooms, they should be run as near to the walls as possible, remembering that there must be a two-inch gap between two pipes, or between pipes and walls for insulation. Pipes that have to be brought into the house from ground-mounted collectors should be routed as directly as possible, avoiding sharp bends and ells.

Expansion

All pipe should be hung or anchored loosely enough so that it can expand and contract with temperature changes. A 100′ length of copper pipe will expand approximately 1″ with a 100°F. temperature rise. Using silicone hoses as expansion joints is advised in arrays where there is no room for pipe expansion. Standard corrugated expansion joints made of copper alloy are also available. Elbows will also allow for some expansion.

Underground Plumbing

Underground plumbing should be well insulated (at least R-4) and buried below the frost line. To keep insulation dry, the pipe should be wrapped in roofing paper and sealed with hot pitch. Buried pipe runs should contain as few joints as possible. Some codes will not allow any buried joints.

Plumbing runs through or under a foundation should pass through an iron pipe sleeve two sizes larger than the insulated pipe and the gap filled with sealant or other approved material. Ask your local plumbing inspector for suggested equivalent protection.

Take care that the pipe does not rest on any rocks in the trench, and do not support it on blocks. Avoid high spots that may trap air. The pipe should rest on firmly packed earth or—if the bottom of the trench is rocky or uneven—a six-inch level layer of tamped sand. If soft soil of poor bearing quality is found at the bottom of the trench, deepen the trench by two pipe diameters and backfill with a layer of fine gravel or crushed stone two pipe diameters deep.

While backfilling the trench, be sure that rocks, broken concrete, or other construction litter does not damage the wrapped and insulated pipe. Six inches of earth should be dumped into the trench, carefully tamped around the pipe to assure proper support and alignment, and then covered with a layer of treated boards to prevent damage to the pipe from future digging. The remaining depth should be filled and tamped at 6-inch intervals to prevent unsightly settling of the lawn.

Sizing

Typically, ½-inch pipe is used for systems utilizing up to three collectors, but certain fittings (for pumps, etc.) will have to be adapted to larger sizes. If total pipe runs are longer than 100 feet, ¾-inch pipe may be required. Headers connecting the collectors should be of sufficient diameter to insure equal flow rates through each individual collector.

Standard pipe friction tables will help you determine the amount of resistance for the type and length of plumbing used. Remember that pipe friction will vary with heat transfer fluid, flow rate, and plumbing material.

Installation Tips

Keep insides of all tubes or pipes clean and ream out the ends of all pipes and tubing. Sandpaper or emery cloth the outside surface of the ends of copper tubing and the inside surface of all copper fittings before soldering. Surfaces must have a bright finish. Bend copper tubing (providing it is annealed or bending temper tubing) rather than use elbows or other fittings. This will reduce friction losses. Avoid sharp bends and use bending tools. Use eccentric reducers to join horizontal pipe of different sizes and avoid trapping air (Figure 3.1).

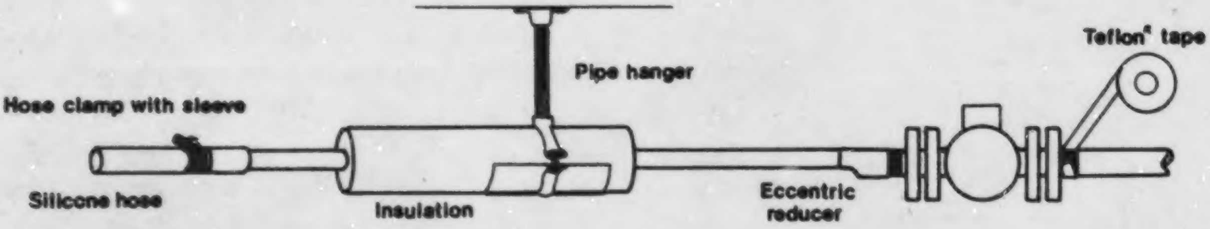

FIGURE 3.1: PIPE LENGTH AND VARIATIONS

Reverse Return Hookups

It is desirable to connect collectors in a parallel reverse return mode. In this mode, the distance the heat transfer fluid travels is equalized (Figure 3.2). Balancing valves can be added for additional flow control if the designer thinks it necessary.

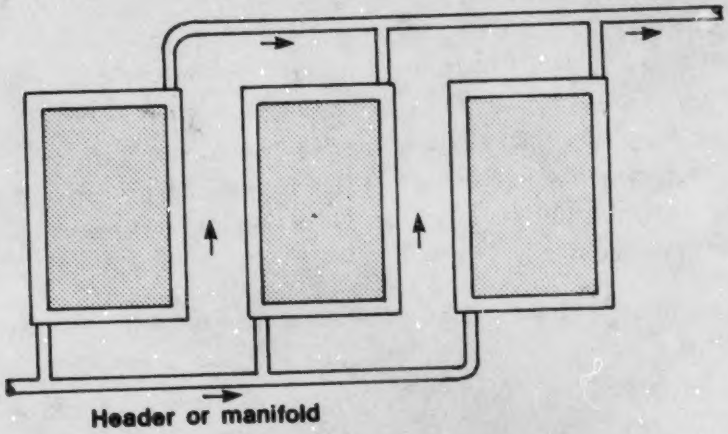

FIGURE 3.2: REVERSE RETURN CONFIGURATION

Series Hookups

Collectors connected in a series mode obtain higher temperatures, thereby reducing collector efficiency. Series hookups are not recommended for solar DHW systems unless specified by the designer (Figure 3.3).

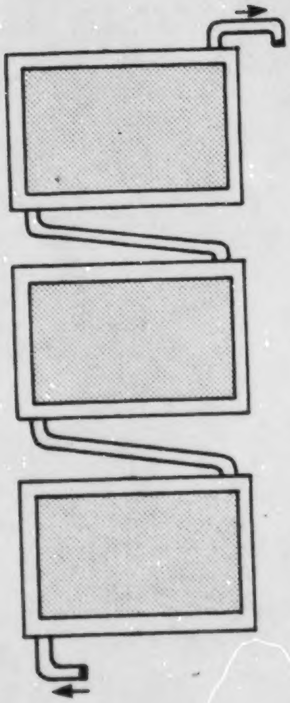

FIGURE 3.3: SERIES CONFIGURATION

DUCTWORK FOR AIR DHW SYSTEMS

Ductwork should not leak more than 5 percent at the design flow rate. Use conventional methods for sizing, employing the minimum gauge allowable to reduce the amount of heat retained within the ductwork.

Because of low-leakage requirements, only metal or properly installed and sealed fiberglass ducts should be used. Take special care when joining ductwork to seal edges on corners. A Pittsburgh lock seam is recommended, and added protection may be achieved by applying a product such as 3M's EC-800® in the seam before joining, and caulking all joints. Joints should be fastened with sheet metal screws or rivets so that the ductwork maintains its integrity through repeated expansions and contractions (Figure 3.4).

Prefabricated swivel ductwork has a tendency to leak more than custom-made ducts. Avoid such items whenever possible.

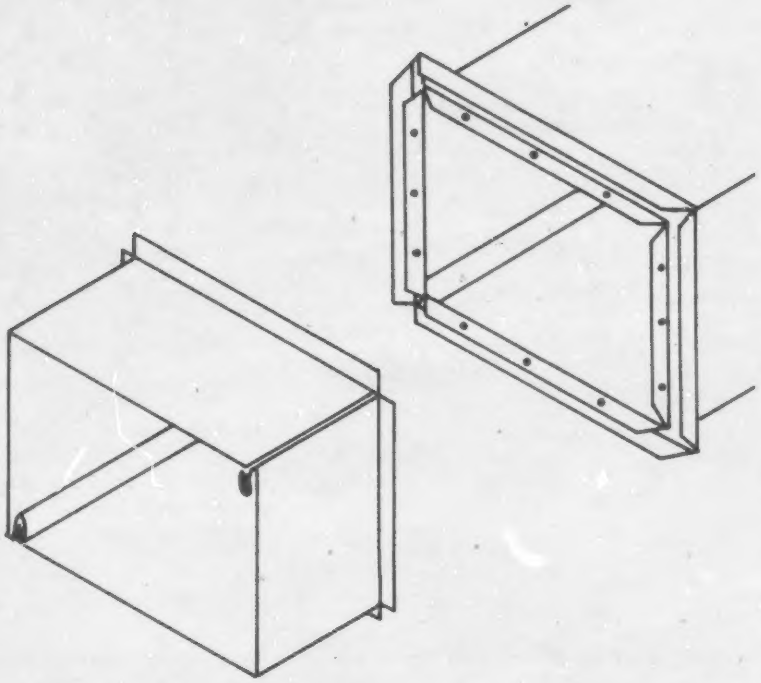

FIGURE 3.4: DUCT CONNECTION

Duct hangers should be spaced according to conventional standards and should wrap around the insulation and not penetrate it. In DHW solar systems, spacing of hangers will typically be 10′ on centers.

INSULATION

Insulating the solar DHW plumbing prior to system startup is an important part of the insulation procedure. You will be expected to supply the pipe and tank insulation. Pipe insulation will usually be of the closed cell foam type or spun fiberglass. Insulate all exposed pipes in the collector loop and all parts of the conventional DHW systems except the city cold water supply. Insulate all elbows, tees, valves, silicone hoses, pumps, and plumbing, butting right up to the collector array and storage tanks. Gouge out insulation to fit over plugs and other hard-to-fit components.

Do not insulate the pump motor housing, tempering valve, tops of air vents (Figure 4.1), or openings in vacuum breakers and relief valves.

FIGURE 4.1: INSULATED AIR VENT (do not insulate cap; seal ends of insulation)

Insulation Materials and Amounts

The most common pipe insulation materials are: fiberglass, elastomers (Armaflex^R, Rubatex^R, etc.), urethane, and isocyanurates (Figure 4.2). The effectiveness of the insulating material is measured in R-values (resistance to heat flow [BTU/hr./°F/ft.^{2}]) or k-value (conductivity [BTU/hr./ft.^{2}/°F/in.]). The higher the R or the lower the k, the better the insulating ability. Some typical values are contained in Table 4.1.

The type of insulation best suited to a given installation depends on local costs,availability, job requirements, and insulating qualities of the materials (Tables 4.1 and 4.2).

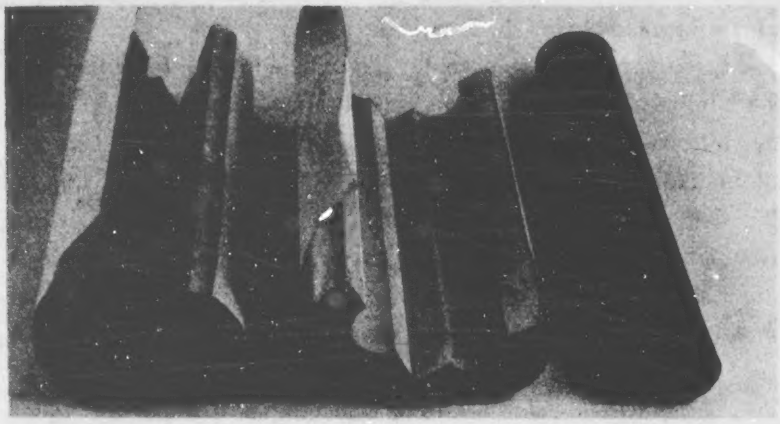

FIGURE 4.2: FIBERGLASS, URETHANE, AND FOAM RUBBER INSULATION

TABLE 4.1. INSULATING VALUE PER INCH OF THICKNESS

Fiberglass	R-3	k-.26
Elastomers	R-3.5	k-.23
Urethane	R-6.5	k-.17
Isocyanurates	R-7+	k-.13

Pipe insulation is usually sold by thickness. For elastomers, ½" is common. Fiberglass and urethanes are generally stocked in one inch thicknesses. One inch of insulation is usually sufficient for pipes under 1" in diameter. This may be achieved with single layers of fiberglass or urethane, or a double layer of the elastomers. As a general rule, pipes under one inch in diameter should be insulated to R-4. Pipes over one inch should be R-6.*

Installing Fiberglass, Urethane, and Isocyanurates

Fiberglass and urethane insulation must be installed after the system hydrostatic pressure test (see chapter on Checkout). Both types of insulation can be bought in preformed halves and must be protected from weather and ultraviolet degradation by a watertight plastic or metallic jacket. Both types of insulation are available already jacketed. The slits in the jacket should be positioned on the downward side of the pipes and taped over with waterproof, weather-resistant tape.

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*Insulating pipes increases the surface area available for radiating heat. Therefore, R-values for pipe insulation are not equivalent to R-values derived for flat surfaces. To calculate R-values for pipe insulation, use the following equation: $R = \frac{\log_e (r_o/r_i)}{2\pi kL}$

Where: r_o = radius of insulation
r_i = radius of pipe
k = conductivity
L = length

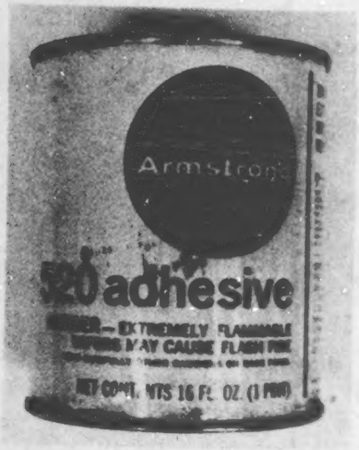

FIGURE 4.3: ELASTOMERIC ADHESIVE

Installing Elastomeric Insulation

This type of insulation is normally put on piping prior to joining. Cut the tube of insulation slightly longer than the pipe to be insulated. Do not stretch. Slide onto the pipe and join by butting. Use the manufacturer's recommended adhesive to seal the joints (Figure 4.3). Slitting and glueing this type of insulation is a less advisable procedure. If necessary, use an adhesive and tape the joints. A small bare spot will cause significant heat loss, so use care. Hold back from joints and valves with clamps or Vise Grips^R until after the system has been hydrostatically tested (Figure 4.4). Expect to have to use two layers of elastomeric insulation to achieve outdoor insulation requirements. Stagger the location of the butted joints or slits when using two layers.

CAUTION! Elastomeric insulation when exposed to the weather will rapidly crack and crumble unless jacketed or coated with a paint approved by the manufacturer. Do not paint over fresh joints. Paint should be reapplied every 3-8 years. Also, elastomeric insulation will decay rapidly if buried without being thoroughly protected from moisture and soil organisms.

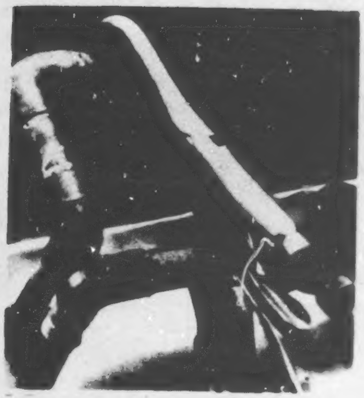

FIGURE 4.4: HOLDING ELASTOMERIC INSULATION WITH VISE GRIPS^R

Installing Pipe Insulation

When insulating around valves outdoors, both valve stems and slits in the insulation should point downward to prevent moisture from getting between pipes and insulation. Another technique is to use elastomeric tape insulation, multilayered, with each layer overlapping the last by 50 percent.

Before painting insulation that is not supplied with its own jacket, wash off the powdery surface with alcohol or toluol. Do not use oil base paints.

Make sure that pipes going through holes in a structure are fully insulated and that holes are properly sealed to prevent leaks and the passage of insects and rodents.

Do not use duct tape on outdoor insulation. Use silicone sealant at the butt of insulation and the collector array. Many of these types of insulation will begin to undergo degradation over 200°F. If you expect higher temperatures than that for long periods of time, consult the manufacturer's literature.

Insulating Air Ducts

Fiberglass, glass wool, and urethane are the most common insulation used. Ducts must be insulated to at least R-4, and insulation must be carefully butted and lapped. Duct work is now available complete with insulation.

Fiberglass ducts at least 1-inch thick may be used indoors if properly grooved, assembled, and all joints taped. Use 1½-inch, 3-pound density insulation or equivalent for sheet metal ducts.

Insulating Storage Tanks

Storage and conventional water heater tanks should be insulated to R-11. A few manufacturers now make tanks insulated to this standard, and you also can buy prefabbed jackets in standard tank sizes. However, it is quite possible that you may have to wrap fiberglass batts around the tanks. Duct tape can be used, and the foil vapor barrier of the batts should face outward. Cover the tank completely and evenly; a surprising amount of heat can be lost through a small gap or thin spot in the insulation. When insulating the tanks of gas- and oil-fired water heaters, be sure the batts are kept a minimum of six inches from the burner so that the insulation backing does not present a fire hazard. You now may purchase tank insulation kits from a number of manufacturers.

PUMPS, VALVES, GAUGES, AND EXPANSION TANKS

PUMPS

In a solar DHW system, the pump is usually a low-horsepower centrifugal circulator of about ¼th to 1/25th horsepower. This pump may be specified by the designer or included as part of a total parts package. However, in some installations you may be called upon to supply the pump, and you must consider several factors in order to choose the right one.

Flow vs. Head

The flow rate is the number of gallons per minute of heat transfer fluid that should flow through the collectors. It is usually between .015 and .04 gallons per minute per square foot of collector surface. The collector manufacturer will specify the most efficient flow rate.

Head is the pressure a pump must push against. There are only two types of head that are of concern to solar DHW installers. These are static and friction, and they must be added together. Typical values are 10′ to 20′ of water. Head varies approximately with the square of the flow velocity.

Friction between the transfer fluid and piping in the system causes pressure losses. These friction head losses can be determined by consulting standard plumbing tables in a number of sources (see Appendix B).

Static head is the height the water must be pumped. Unlike pressure loss, it has no relationship to the length of the heat transfer fluid circulation loop. Static head is a factor in an open-loop system, such as a draindown system, because each time the pump starts it must move fluid to the top of the collector. It is not a factor in closed-loop systems.

In a siphon draindown system, once the fluid has been circulated throughout the system, the static head disappears since the loop is closed. However, static head must be considered in sizing the pump. In certain installations, multiple controllers or multiple pumps may be required.

Transfer fluids other than water will affect pump performance. Correction factors for viscosity (which affects friction head), specific heat (which affects flow rate) and specific gravity must be used. Information on such correction factors is available from transfer fluid manufacturers (see Appendix C).

Open vs. Closed Loop

Determine if the loop ever will be exposed to air. In a closed antifreeze system, a cast iron pump can be used. A draindown system, where air will enter, requires a bronze or stainless steel pump to prevent corrosion. Galvanized pumps should not be used with glycol/water heat transfer fluids.

Seals and Transfer Fluids

Magnetically driven pumps have no seals to wear or leak. The pumps can be used with any transfer fluid, if compatible with other pump materials. Polyethylene and polypropylene seals are attacked by petroleum-based transfer fluids, so pumps without seals or those with seals made of materials such as Viton^{R} should be used.

Selecting a Pump

With the above points in mind, consult the catalogs and literature of several manufacturers of appropriate pumps and examine the performance curves. Pump curves plot flow (horizontal axis) versus head (vertical axis). Friction head varies with the square of the flow rate. For example, if the flow doubles, the friction head is quadrupled (Figure 5.1).

Pick a pump that most closely matches the design curve of the system you are installing. That curve is a product of the total head pressure (which you must determine) and the collector flow rate specified by the collector manufacturer.

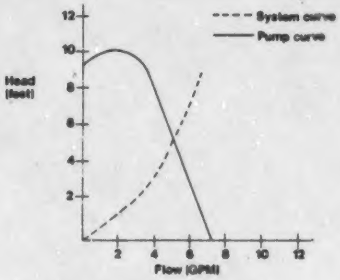

FIGURE 5.1: PUMP AND SYSTEM CURVES

In some cases, two or more pumps in series may be necessary because of increased static head or a large number of bends in the pipe. If there is less head than expected, it is possible to reduce the flow rate. However, you must remember that the cooler a flat-plate solar collector runs, the higher its efficiency. Thus, reducing the flow rate in order to install a smaller pump for the same given head is a poor economic trade-off.

Select a durable pump. It will have to run for long periods of time at high temperatures and pressures. A pump failure could cause the collectors to stagnate and damage the DHW system.

Installation

Install the pump on a separate 15-amp service line to prevent any possibility of overload and pump failure. The pump should be located on the supply side of the collectors, as close to the supply as possible, and below the top of the tank to retain its prime. Consult the manufacturers' literature for proper operating positions. Some pumps will wear out bearings rapidly if the motor shaft is not in a horizontal position. Check arrows on the pump to see if the flow is in the proper direction (Figure 5.2). The pressure gauge also will tell you if the impellor is running in the right direction. Some pumps can easily be installed backwards. Make sure the pump is supported adequately on both sides if it is heavy enough to need support. Locate the pump where maintenance will be easy. The pump can be insulated, but the motor housing must not be, or the

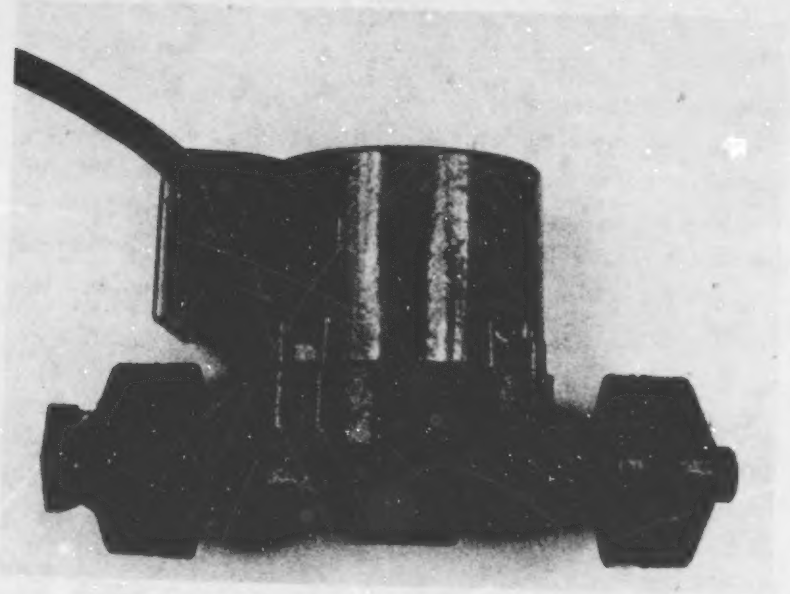

FIGURE 5.2: PUMP (NOTE ARROW)

life of the pump will be shortened greatly. Install a strainer with a brass or stainless steel screen ahead of the pump to remove metal filings, sediment, etc. that might damage the pump, clog collector passages, or cause galvanic corrosion in the system.

Pump Operation

It is important not to lose prime during system operations. Running air-bound for more than 10 seconds will damage the pump if it is not self-priming. In draining down, the pump must be below the water level in the tank to retain prime.

When you start a system, the pump may make some noise because of air bubbles. This noise is harmless and will diminish as the air bubbles find their way out through the air vent valves. If the bubble noise continues, check the system for leaks.

VALVE AND GAUGE SELECTION

Special attention must be given to the selection and placement of valves in a solar DHW system. Most of the plumbing is no different from that of a conventional DHW system, but the solar DHW system may have a collector loop separate from the regular plumbing and may use toxic or nonpotable heat transfer fluids. A variety of valves and components often needed for the safe operation of a solar DHW system are described below. Required components and their settings will vary slightly from one packaged system to another.

Backflow Preventer

An approved backflow preventer on the city water supply may be required in some code jurisdictions for any solar DHW system that uses a nonpotable heat transfer fluid. A check valve is NOT a substitute for an approved backflow preventer and should not be used in its place. Check local codes for requirements in your area (Figure 5.3). Since a residential type backflow preventer may discharge in any direction, it should not be installed near electrical components or items which might be damaged.

FIGURE 5.3: BACKFLOW PREVENTER

Check Valve (One-Way Valve)

Check valves are designed to permit liquid flow in only one direction. They should be installed in closed-loop systems to prevent reverse thermosiphoning of heated water from the storage tank into the collector array. A number of designs are available for horizontal and vertical piping installations. Use of swing check valves on vertical piping is not recommended because low thermosiphon

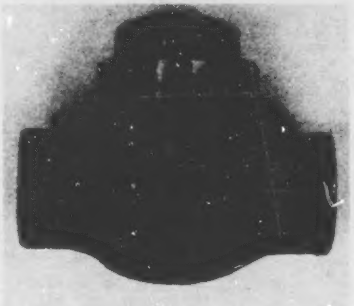

FIGURE 5.4: SWING CHECK VALVE

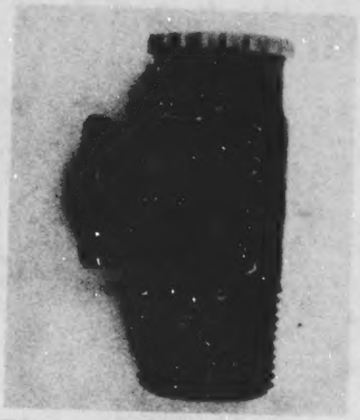

FIGURE 5.5: PRESSURE RELIEF VALVE

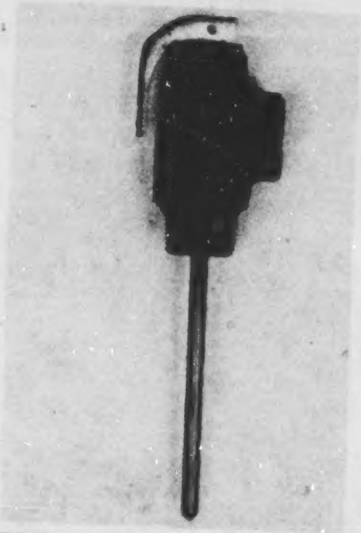

FIGURE 5.6: TEMPERATURE AND PRESSURE RELIEF VALVE

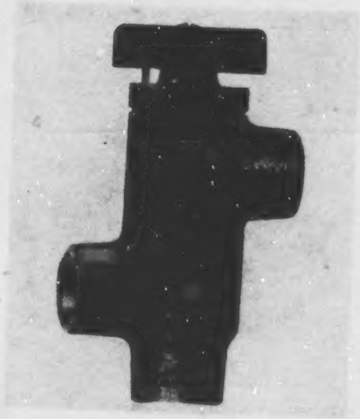

FIGURE 5.7: MIXING VALVE

pressure may not completely close the valve. When installing, be sure the arrow on the valve is pointed in the desired direction of flow. Check valves also should be installed in the drain loop of draindown systems to direct water through the collectors properly while the system is operating. Usually a swing check valve mounted horizontally is preferable to a spring check valve mounted vertically in a small pump system (Figure 5.4).

Pressure Relief Valve

Pressure relief valves are designed to allow transfer fluids to escape from a closed loop if maximum working pressure is exceeded (usually 30 to 45 psi).

If the system is not operating and the collectors reach stagnation temperature, the pressure relief valve will permit steam to escape and prevent damage to the system. The relief valve may be installed anywhere along the closed loop, but the general practice is to install it in the return side of the loop near the expansion tank and on the suction side of the pump. There should be a relief valve between all closable valves. Collectors must not be allowed to be isolated without a relief valve in the line. The relief valve should be either installed AFTER pressure testing or plugged during the test.

Discharge from a pressure relief valve will be very hot and should be connected, therefore, to a waste drain or a container. If discharge occurs on the roof, damage or discoloration of roofing materials might result. A glass container is recommended so that any fluid discharged will be noticed, indicating the need for replacement of the fluid. If connected to a drain or a dry well, the end of the pipe should NOT be threaded (see chapter on Safety) (Figure 5.5).

Temperature and Pressure Relief Valve

Temperature and pressure relief valves are similar to pressure relief valves but contain a temperature-sensing element at the valve inlet that extends about six inches into the top of each storage tank where the hottest water is stored. Valve limits are usually set to 125 psi and 210°F. Ratings should be listed on the valve. These valves are sometimes installed in the upper end of a tee fitting. The lower end of the tee should be connected by tapping into the top of the tank by means of a close nipple. The hot water supply line is connected to the branch of the tee.

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Temperature and pressure relief valves should be connected to within 6 inches of a waste drain or dry well to prevent unexpected discharge from scalding occupants or service personnel. The end of the pipe should NOT be threaded (Figure 5.6).

WARNING!

Operating a hot water tank or two tanks in series without a temperature and pressure relief valve is extremely dangerous and is ILLEGAL IN MOST AREAS. Check your local building codes carefully on this point.

Tempering or Mixing Valve

This valve is used to add cold water to the flow of water from the storage tank that exceeds a preset temperature, usually between 120° and 140°F. This allows the collection of hotter solar water while protecting users from being scalded. Some mixing valves are adjustable. It should be installed 12 inches below the hot water outlet with cold water entering from the bottom (Figure 5.7).

WARNING!

The heat-sensing element of a tempering valve must be removed before soldering and replaced afterwards. High soldering temperatures will render the sensing element useless.

Pressure Reducing Valve (Pressure Regulator)

Pressure reducing valves are often used in conventional water supply systems to reduce incoming water pressure and prevent damage to some components. These valves are usually installed when the incoming pressure is greater than the working pressure of any component, such as parts of a draindown system. Pressure reducing valves should be preceded by a strainer and isolated by shutoffs for cleaning (Figure 5.8).

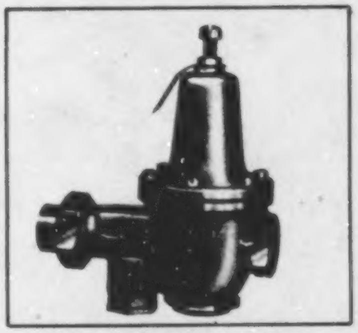

FIGURE 5.8: PRESSURE REDUCING VALVE

Air Vents

Air vents eliminate air bubbles from the system. Vents are installed at the high points in the system, usually in the collector manifold and above the air eliminator (see Air Eliminator).

Of the two main types of vents, the manual vent is the least common. It is opened and closed by hand, and with roof-mounted collectors operation becomes impractical.

Automatic float vents are the most commonly used. The cap on the automatic air vent must not be tightened; it should sit loosely on the threads. It is there only to prevent entry of dust or water which would clog the port. The vent MUST be mounted vertically (Figure 5.9).

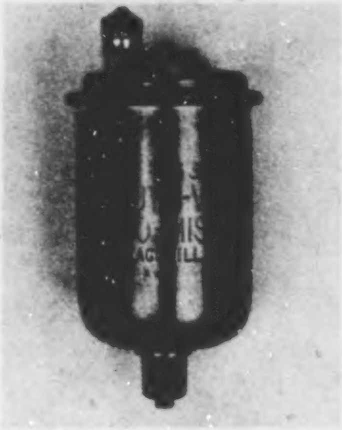

FIGURE 5.9: AUTOMATIC AIR VENT

CAUTION! As a last step in any float vent installation, tighten the cap and then loosen it a full two turns.

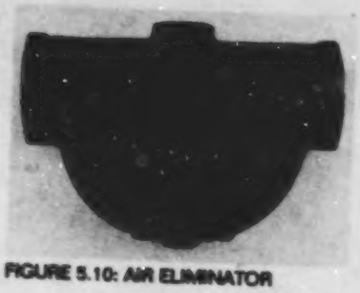

FIGURE 5.10: AIR ELIMINATOR

Air Eliminator (Air Separator)

An air eliminator also removes air from the heat transfer fluid. The fluid flows across a series of baffles that causes air to bubble up out of the fluid stream. It is then eliminated through an automatic air vent threaded into the top of the scoop. Eliminators are usually installed above the expansion tank and include threaded fittings that will mate with most sizes of tanks (Figure 5.10).

Balancing Valve

A balancing valve can be used to control the flow of heat transfer fluids through each collector panel in those systems that do not have a reverse return piping arrangement. A proper flow velocity through each collector is necessary for optimum efficiency. The simplest and least expensive type is the square head cock, which is installed between each collector and the manifold, downstream from the pump to prevent cavitation. Ball or globe valves are also commonly used. Do not use a gate valve for balancing.

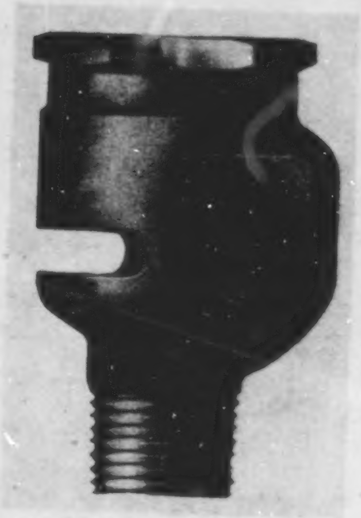

FIGURE 5.11: VACUUM RELIEF VALVE

Solenoid Valves

Solenoid valves are electrically operated valves used in draindown systems to start and stop (as well as divert) the flow of heat transfer fluid. Most draindown systems use two such valves: one normally open and one normally closed. When a freezing condition exists or electrical power fails, the valve which allows fluid to circulate to the collectors closes and the valve used to drain the system opens. This procedure is reversed when the weather is warm and sunny. Solenoid valves may require some regular maintenance. In regions with infrequent freezing, its operation should be checked occasionally.

Three-Way Valves

Three-way valves are not recommended because of their tendency to leak through the closed part. Instead, use two or more regular valves.

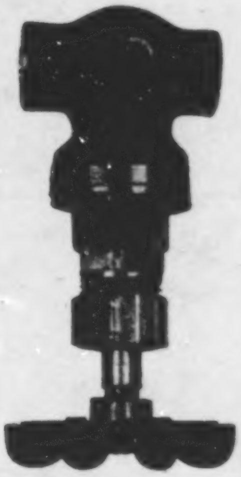

FIGURE 5.12: ISOLATION VALVE

Vacuum Relief Valves

Vacuum relief valves are used in draindown systems and are installed at the high point of the system above the collector. This valve permits the system to drain, using gravity by admitting atmospheric pressure into the return piping. It is sometimes installed above the cold water inlet of storage tanks to eliminate vacuum conditions that could collapse the tanks (Figure 5.11).

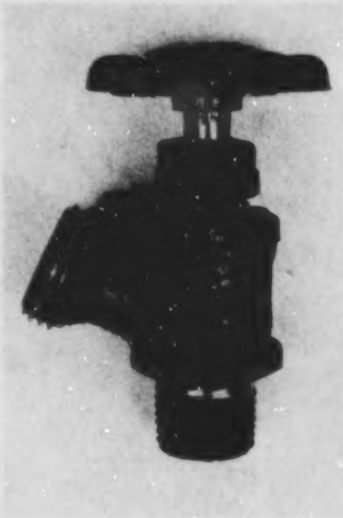

FIGURE 5.13: BOILER DRAIN

Isolation Valves (Shutoff Valves)

Isolation valves should be installed to permit certain components to be serviced without having to drain and refill the system.

To avoid unauthorized tampering with the system, use tool-operated valves or remove the valve handles and store them in a safe place (Figure 5.12). Globe valves should not be used because they restrict flow and reduce system efficiency.

Isolation valves should be placed at the following locations:

1. One on each side of the circulator pump and strainer.
2. One at the cold, or city water, supply inlet (to shut down the entire system).
3. One on either side of an external heat exchanger for servicing.
4. One on each side of the screen ahead of a pressure regulator.

WARNING!

Isolation valves should not be installed in a way that could isolate collectors from pressure relief valves or temperature and pressure relief valves, and the expansion tank. If this occurs, collectors could burst during stagnation conditions.

Fill Valve

A fill valve is usually a gate valve with an open end facing up. It is used at the high point in some systems for manual fillup with heat transfer fluid.

Boiler Drain Valve

There should be one boiler drain valve at the bottom of the storage tank for draining and periodic cleaning. There should also be two on the collector loop near the storage tank. These two valves are used for charging up the system using a pump (see chapter on Checkout), and they should be separated by an isolation valve, which can be closed for system charge-up until the air is purged. After the system is charged and capped, remove the valve handles and label the valves with the charge-up date (Figure 5.13).

Pressure Gauge

A pressure gauge should be installed on the collector loop or on the top of the air eliminator (Figure 5.14).

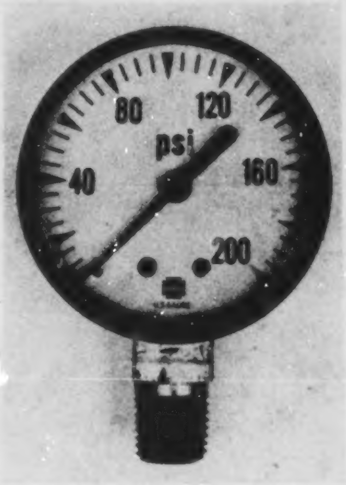

FIGURE 5.14: PRESSURE GAUGE

Thermometers

Thermometers are not absolutely necessary, but they can provide useful information to the homeowner and service personnel. Placing thermometers on the feed and return ends of the collector circulation will give some indication of how the system is working. Use button-type thermometers or probe types with diameters of less than $^3/_{16}$-inch that block less than 20 percent of the pipe diameter. Thermometers with larger probes can be used if installed in a proportionately larger fitting. A clamp-on type thermometer can be useful also.

Combination Temperature/Pressure Gauge

A combination gauge provides both temperature and pressure information on one instrument.

Elapsed Time Meter

An elapsed time meter can be temporarily or permanently installed on a pump to determine when and how long it is running and, therefore, whether the system is operating properly (see chapter on Checkout).

DAMPER

Dampers are used to control the flow of air in an air system. Make sure that dampers have positive seals, correct installation, and proper functioning. Leaks of cold air can cause the heat exchanger to freeze up and will also decrease system efficiency.

EXPANSION TANK

An expansion tank is a necessary component of a solar DHW system which has a closed circulation in the collector loop. As the temperature of the heat transfer fluid in the loop rises, the volume of fluid expands. The apparent expansion rate per degree rise will depend on the heat transfer fluid used (Figure 5.15).

For example, water has an apparent expansion rate of .025 percent per degree of temperature rise. A 50-gallon volume of water at 60°F. will expand to 51.75 gallons at 200°F. The expansion tank must compensate for this variation in volume to keep system pressure below the maximum pressure allowed for the system components.

If the temperature and pressure in the system rise beyond preset limits, the pressure relief valve will blow off fluid to keep the system functioning within the allowable pressure range.

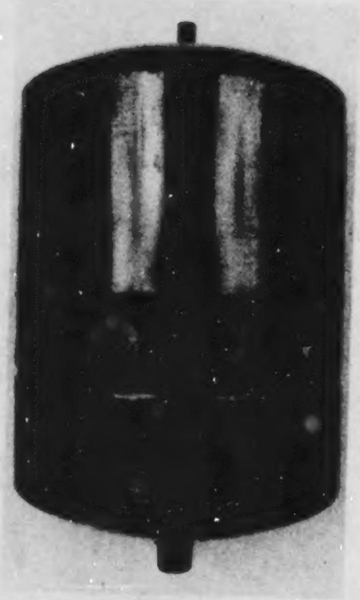

FIGURE 5.15: EXPANSION TANK

Nonpressurized open systems do not require a separate expansion tank because volume variations are usually handled by the storage tank.

Diaphragm or Bladder Expansion Tank

This tank contains a flexible diaphragm with an air charge on one side and heat transfer fluid on the other. As the fluid changes temperature and volume, the bladder compresses the air charge and makes room for the expanding fluid.

Nondiaphragm or Expanding Expansion Tank

This tank operates in essentially the same way as a diaphragm tank, but because there is no diaphragm, some mixing of air and heat transfer fluid will occur. Open nondiaphragm tanks must be mounted near the highest point in the system with the air chamber at the top. This may mean placing it outdoors. Closed nondiaphragm expansion tanks can be located anywhere in the system.

Sizing Expansion Tanks

Manufacturers of specialized heat transfer fluids should provide expansion factors for properly sizing expansion tanks. Glycol mixtures, for example, require a slightly larger expansion tank than would be necessary for an equal amount of water.

Installation

The expansion tank should be placed on the suction side of the pump in the collector loop. A diaphragm tank can be installed either upward or downward without seriously affecting performance. Downward is preferred to reduce heat loss. A pressure gauge should be provided by the manufacturer for installation with the expansion tank. Do not tamper with or adjust the preset valve. The air side of an expansion tank is prepressurized by the manufacturer. If it is necessary to change the air charge in the tank, there is a threaded valve on the tank bottom.

CAUTION!

Do not install the tank until after the system is pressure tested because the tank may be damaged during testing. Also, do not use a galvanized expansion tank with a water/glycol heat transfer fluid.

CAUTION!

Butyl rubber diaphragms will deteriorate when in contact with oils or water/glycol heat transfer fluids. If glycols are being used, the diaphragm should be neoprene or some other suitable material. Oils require a nondiaphragm expansion tank.

CAUTION! If an expansion tank suddenly loses pressure, do not simply repressurize it. Loss of pressure may indicate a leak in the diaphragm (if the tank has one) or some other system malfunction.

HEAT EXCHANGERS AND STORAGE TANKS

Heat exchangers and storage tanks can be considered functionally together. Heat transfer fluid passing through the heat exchanger heats domestic water in the storage tank or tanks. In many systems, heat exchangers will actually be immersed in the storage tank. Many solar DHW system component suppliers sell exchangers and storage tanks as complete units. However, you may find yourself installing a separate storage tank and heat exchanger, or even fabricating a storage tank-heat exchanger unit on-site. Therefore, this chapter includes a full description of various types of heat exchangers and storage tanks.

HEAT EXCHANGERS

Heat exchangers are used to transfer thermal energy from one medium to another across an enlarged surface area. Heat exchangers separate the heat transfer fluid in the collector loop (either air or liquid) from the domestic water supply in the storage tank. By using a heat exchanger, only a small portion of the total amount of fluid must be treated to prevent system corrosion or freezing. Although heat exchangers are usually built into or around the hot water storage tank, they also can be separate units.

Types of Heat Exchangers

Solar DHW heat exchangers can be either single- or double-walled. While both liquid-to-liquid and air-to-liquid heat exchangers are used in solar space heating systems, most solar DHW systems use a liquid-to-liquid heat exchanger.

Thermosiphon and draindown systems do not use heat exchangers. The domestic water supply itself is circulated through the collectors. Drainback systems employ a single-walled liquid-to-liquid heat exchanger, with both fluids being water.

Systems using transfer fluids other than potable water (see chapter on Transfer Fluids) in the collector loop are required by HUD's IMPS to have double-walled heat exchangers if the fluids are nonpotable as defined by either IMPS or by the local health authority having jurisdiction. Extra thick single walls are not considered acceptable protection, nor are single-walled configurations depending on potable water pressures to prevent contamination. Suppliers of the heat transfer fluids used in the system you are installing may be consulted about the required degree of separation.

Heat Exchanger Designs

There are currently a number of different heat exchanger designs that can be used in a solar DHW system.

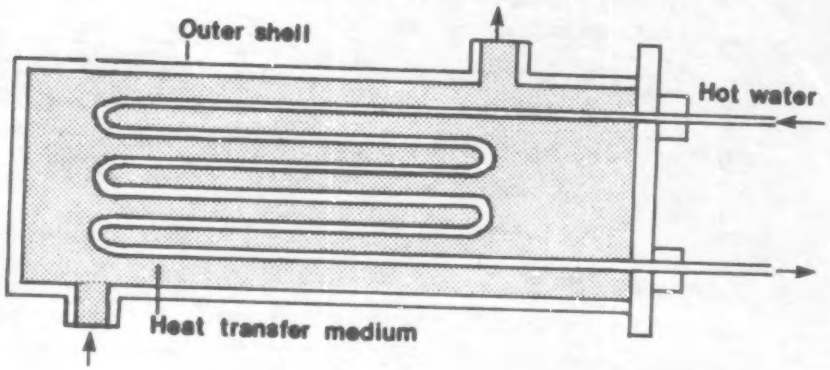

FIGURE 6.1: SHELL AND TUBE HEAT EXCHANGER

Shell-and-tube heat exchangers consist of an outer casing or shell surrounding a bundle of tubes (Figure 6.1). The transfer fluid circulates between the shell and the tubes of water. The tubes are usually steel, copper, or sometimes stainless steel. This type of heat exchanger cannot be used with a nonpotable transfer fluid unless two are used, but it can be used with a drainback system.

There are several types of double-walled heat exchangers. A double separation is always required when a nonpotable transfer fluid is used. One type consists of tubing wrapped around and bonded to a tank (Figure 6.2). Potable water can circulate either through the tubing or the tank. There must be good thermal contact between tank wall and tubing, and the unit must be covered with insulation to reduce heat losses.

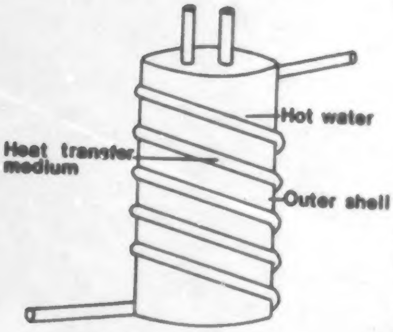

FIGURE 6.2: WRAP-AROUND HEAT EXCHANGER

Tube-in-tube exchangers consist of tubes of domestic water and collector heat transfer fluid in direct thermal contact (Figure 6.3). There is no intermediate heat transfer fluid. The outer tube may be finned to help transfer additional heat. This type is suited for non-potable heat transfer fluids.

Parallel-tube heat exchangers (Figure 6.4) consist of parallel tubes in continuous contact in which the heat transfer fluid and the fluid to be heated flow in opposite directions.

Air-to-water heat exchangers consist of a finned water coil in a closed duct on the hot air return side of an air collector array (Figure 6.5) or a coil buried in the rock storage bin of an air space heating system.

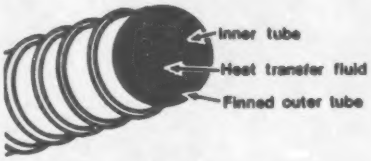
Inner tube
Heat transfer fluid
Finned outer tube

FIGURE 6.3: TUBE IN TUBE HEAT EXCHANGER

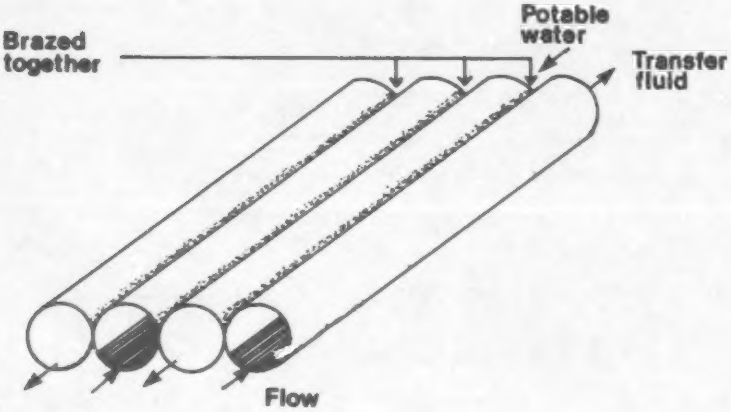
Brazed together
Potable water
Transfer fluid
Flow

FIGURE 6.4: PARALLEL TUBE HEAT EXCHANGER

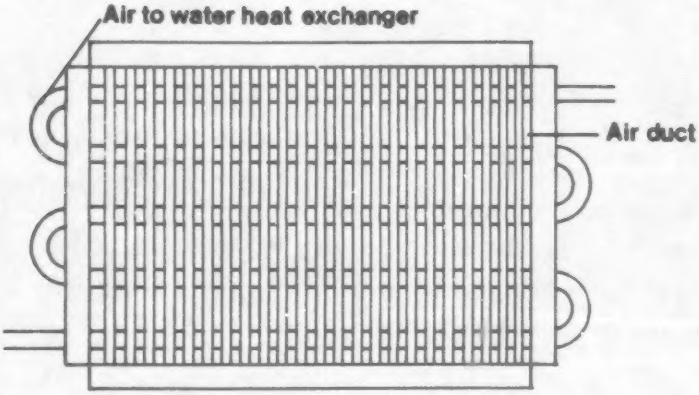
Air to water heat exchanger
Air duct

FIGURE 6.5: AIR TO LIQUID HEAT EXCHANGER

Sizing Heat Exchangers

Most heat exchanger manufacturers use computer programs to choose the proper heat exchanger for specified temperature and flow conditions. Manufacturers should supply heat exchangers with ratings indicating heat (in BTU's per hour) that will be transferred when supply side and load-side entering temperatures and the flow rates of both sides are known. If the manufacturer's literature does not supply adequate information, contact the technical sales department for additional information.

Installing Heat Exchangers

In most solar DHW systems, the exchanger will be a coil immersed in one of the hot water tanks. If an external type heat exchanger is used, be sure that it is adequately supported and well insulated. Be sure pipe connections to it and from heat exchangers are in accord with prescribed flow. Allow room for maintenance and drainage if the heat exchanger is a separate unit.

STORAGE TANKS AND SYSTEMS

Water is by far the most common storage medium in solar DHW systems. Rock storage is another method of sensible heat storage, but is not generally used in systems that are exclusively DHW. Storage of heat in solutions of phase-changing salts is extremely rare in DHW systems and therefore is not discussed.

Single-Tank vs. Two-Tank Systems

The backup conventional DHW heater can be installed as part of the solar DHW storage tank or hooked in series with it. For example, a single-tank solar DHW system can be made from an adapted electric water heater of sufficient size by disconnecting the lower of the two electrical heating elements from the power source. There are also tanks now available with one element in the middle for solar applications. In draindown and drainback systems, the collector supply line outlet is generally located in the lowest third of the storage tank to draw out the coldest water and circulate it through the collectors so they will work at highest efficiency. Combining both auxiliary and solar DHW storage in one tank does reduce the system's storage volume. A one-tank solar DHW system will probably require a larger tank than conventional DHW systems.

In a two-tank system the solar DHW tank serves as a preheat tank and has a cold water inlet. Supplemental heating takes place in the conventional DHW tank. Two tanks require more floor space, and standby losses will be greater. But collectors often will receive lower inlet temperatures, improving their efficiency.

The source of auxiliary heat is also a consideration. Because a gas hot water heater will not stratify, two tanks may be more desirable. An electric backup with the lower element disconnected may function better in a one tank configuration.

Types of Storage Tanks

You probably will install only two types of tanks: steel or fiberglass. Steel tanks are usually lined with either glass or concrete (stone-lined). Stone-lined tanks are heavier; size and weight specifications are available from manufacturers. If the fluid in storage is pressurized, tanks larger than 120 gallons must carry an ASME label, indicating that its construction conforms to accepted standards of safety.

Fiberglass tanks are lighter than glass- or stone-lined steel tanks and are highly corrosion resistant. You should check pressure and temperature ratings of this type of tank to see if it will withstand the maximum pressures (100 psi or more) and temperatures imposed by the system you are installing. Most fiberglass tanks cannot be used to store water as high as 220°F., even if unpressurized. As pressure increases, its temperature limit decreases.

Tanks must have provisions for all supply and return lines. Tanks can have either built-in heat exchangers (if any are required) or separate units that you install.

WARNING!

Temperature and pressure relief valves are mandatory for all hot water storage tanks or in at least one tank of a two-tank system.

Inspecting Storage Tanks

After the tank is delivered to the job site, check it for obvious signs of damage. You may want to pressure test it before putting it in final position, because the tank may be difficult to move once properly placed. Check the condition of the in-tank heat exchanger, if there is one. If the heat exchanger coil is suspended in the tank, bouncing around during shipment may have damaged it. Reject damaged tanks immediately.

Plug all tank openings to prevent dirt from entering. If space considerations permit, leave the tank crated until the move is completed. If the tank is to be lowered into a basement, you may need a winch, especially if it is a stone-lined tank. In most cases, at least two people and a hand truck will be necessary. Take care not to damage the tank while moving it into place.

Placing Storage Tanks

The best storage tank placement is near the existing DHW components with protection from moisture and cold, near the point of use, and in an area where drainage, leakage, or valve-venting will not cause damage. In most cases, this would probably be in a cellar or an enclosed porch.

WARNING! Storage tanks should not be installed in areas where flammable liquids are stored.

For thermosiphon systems, the storage tank must be a minimum of 18" - 24" above the top of the collector array, which may require placing the tank on an outside platform, the roof (depending on collector location), or possibly in the attic.

Tanks should be level and upright (if at all possible) to obtain the best thermal stratification of the hot water. If a tank is placed in a basement or other unfinished area, placement should be on a concrete pad to ensure that it stays level. A tank below grade should be set up on blocks to prevent corrosion in case of flooding.

In a two-tank system, the storage tank should be as close as possible to the conventional hot water heater and the electrical hookup, but keep enough room between them to conduct maintenance and repairs.

Installing Storage Tanks

After the tank is in place, shut off the main water supply to the existing water heater (if this is a retrofit installation) and bleed off enough water to empty the supply line. Connect to the rest of the solar DHW system (see chapter on Transfer Fluids). Pipe connections should be provided with the tank. When plumbing the solar storage tank in series with the conventional DHW tank, always bring the cold water supply into the solar storage tank first.

When installed, the storage tank should be leak tested before insulation is added (see chapter on Checkout).

SYSTEM CONTROLS

The task of the controller in a solar DHW system is to make the system collect as much useful heat as possible and deliver it to meet the hot water demands of the system's users. The three basic components of a controller are the sensor subsystem, the differential thermostat, and the output subsystem.

The Sensor Subsystem

Sensors measure temperatures in various parts of the solar hot water system and send signals to the differential thermostat. Several types of sensors are used in solar applications. Sensors should be able to withstand collector stagnation temperatures. Because the controller generally is calibrated for a particular sensor, use the sensors supplied by the manufacturer. One sensor is mounted at the bottom of the preheat storage tank and the other on the collector absorber plate or on the outlet pipe. Always double check to see that you have mounted the proper sensor in the correct location.

Some differential thermostats allow for a third sensor. A temperature-limiting device or high-limit aquastat will work in conjunction with a tank sensor mounted at the top of the tank. This device can be set at a maximum desired temperature and will stop circulation of heat transfer fluid through the collector loop by cutting power to the circulator pump whenever the cutoff temperature is reached. In a draindown or drainback system, this will prevent fluid boiling in the collector loop. Along with the mixing valve, it also provides added protection against scalding.

In a draindown system, a low-set or frost-cycle sensor is installed for freeze protection. This sensor measures ambient air temperature or collector header temperature and drains the system of water when the temperature drops to a preset low. When there is available sunshine and the pump is operating, the differential thermostat automatically overrides the frost sensor to prevent draining the collector loop.

The Differential Thermostat

The differential thermostat receives signals from the sensors and uses this input to control the system. It is usually factory-set for high and low temperature differentials to maximize the amount of heat energy collected and stored, and to minimize excessive cycling. This reduces wear on pumps, blowers, and relays and minimizes the amount of power necessary to operate the solar DHW system.

Most differential thermostats are of the on-off type; the pump or blower is either full on or off. Typically, the system comes on when there is a 10°-18°F. positive temperature difference between collector and storage and shuts down when there is a 3°F. temperature difference.

Proportional differential thermostats are available that can vary pump or blower speeds as a function of the temperature differential between collector outlet and storage. Proportional controllers are not recommended for drainback or draindown systems because pumps may not receive enough power initially to fill the system at a reasonable rate. Be sure to use the size and type of wire specified by the manufacturer.

The Output Subsystem

The output subsystem delivers the appropriate control voltages from the differential thermostat to pumps, valves, fans, or dampers.

Switching is done with either conventional relays or with solid state relay circuits. Conventional relays withstand momentary overloads caused by accidental shorting or by close lightning surges.

Surges will instantly destroy solid state relays. Therefore, the installation must be done properly so that no unusual loads or surges occur. Some controllers have built-in protection against power surges. For pre-wired pump/control combinations, solid state relays are a good choice.

Preparing for Installation

Proper installation of the controls is crucial to the safe and economical operation of the solar DHW system. The system manufacturer or his representative should either provide the control equipment as part of the system package or specify it. Study the wiring diagram. The equipment should be accompanied by complete wiring instructions. If instructions are unclear, you should consult the controller manufacturer.

Mounting the Control Panel

The control panel consists of the differential thermostat, assorted relays, and other equipment included by the manufacturer. The panel should be mounted in a well-ventilated location that allows easy access for maintenance and system operation. It also should be far enough away from storage tanks and plumbing so that leaks and drainage will not dampen the floor under it. A dry wooden platform should be provided for workmen.

All controls and equipment must be properly grounded and plug-in connectors should have built-in grounds. All equipment requiring electrical connectors over 50 volts should have a positive means of disconnect adjacent to and in clear sight of the controller and other equipment.

Locate the system on a separate unswitched circuit or, if necessary, one with a very light load. Remember that failure of the controller because of an overloaded circuit could result in expensive damage to the solar DHW system. Power supply to the controller is usually 120 volts. All wiring and equipment must be installed in conformity with state and local codes. The control system wiring is low voltage, usually 24 volts, and 20- or 22-gauge thermostat or bell wire is usually used. Shielded wire should be used if there is evidence of high voltage interfering with the low voltage signal.

Wiring

Rough-in service wiring from the control panel to the sensor locations, valves and pumps (in liquid systems), or dampers and blowers (in air systems). Wire runs should be as short as possible. Wiring should be color coded and labeled. Make sure the wire you have selected can handle the system load. Outdoor wiring with weatherproof cover should be used for the run from the collector sensor to the controller. It can be run along the return line through the pipe flashing and secured to the pipe insulation with plastic strap clips. All wires and cables should be supported along runs, and electric cable must be securely anchored to junction boxes. All low voltage wire should be soldered (using rosin flux) to obtain the most accurate signal transmission.

Mounting Collector Sensor

The collector sensor works most effectively when attached to the back of the absorber plate, but it also will work well if attached to the first 3 inches of the collector outlet pipe at the top of the collector. Ideally, the sensor should be immersed in the heat transfer fluid leaving the collector. However, sensor probes should not protrude into the collector piping and impede the flow of the heat transfer fluid. Some manufacturers supply collectors with sensors already attached.

The sensor can be attached to the absorber plate with a clip or bolt. The sensor should not touch the walls of the collector box because the box will act as a heat sink and will produce lower temperature readings.

CAUTION! Do not bend the sensors; this can affect the readings. Do not solder the sensor to the absorber plate or storage tank.

The sensor can be attached to the collector outlet pipe with a hose clamp or a pressure clip. Certain types may be installed in a T-fitting (Figure 7.1). Take care that the T-fitting does not leak and that the sensor does not restrict the fluid flow. In an air system, the collector sensor can be placed in the air duct just outside the collector hot air outlet and held in place with sheet metal screws.

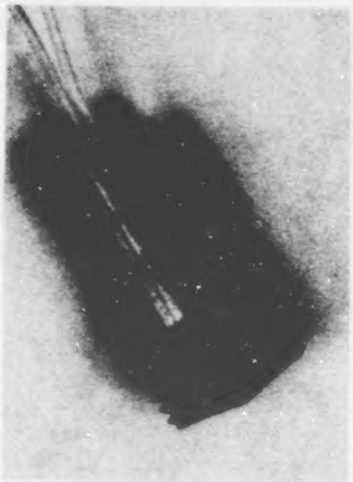
FIGURE 7.1: SENSOR

However the sensor is attached, be certain that there is good thermal contact with the underlying metal. Thermal cement can be applied between the sensor and the underlying metal to ensure good heat transfer. Thermal cement alone should not be relied on to maintain a good mechanical attachment. The sensor should be adequately insulated so it is not affected by ambient air temperature. It should be protected under the insulation by a layer of waterproofing tape capable of withstanding high temperatures.

Mounting Tank Sensor

The location of the sensor in the storage tank depends upon the placement of the collector outlet sensor and the differential thermostat (some are adjustable). In a one-tank system (solar storage and conventional heater in one tank) the sensor should be in the bottom third of the tank. Some sensors can be installed by mounting them to the outside metal surface of the actual tank using thermal epoxy. Do not drill into the wall of a lined storage tank. Remember that the tank must remain watertight. Do not mount in a temperature pressure fitting.

Some tank sensors are available as threaded, pre-assembled, sealed units. Be sure the threads are watertight. Bulb-well sensors require thermal cement to hold them in place.

Mounting Frost Sensor

Frost sensors for draindown systems should be placed in a moisture-protected and unheated location near the collectors, such as under the eaves of the roof. Frost sensors should NOT be insulated.

Hookup and Testing

Before working on a circuit, remove the fuse or trip the circuit breaker. DHW systems are manufactured for a specific phase and voltage; incorrect voltage may damage the controls. Check before hooking up the system.

Before wiring the thermostat to the circulator pump, check the pump circuit for a short or a ground fault that could damage the thermostat and void the warranty.

Make sure that the controls isolate the backup circuit from the solar circuit so that the auxiliary heater is not affected if the solar energy system breaks down.

SAFETY

Solar DHW systems are no more hazardous than conventional domestic hot water systems. Indeed, with a few important exceptions, the safety precautions to be followed in installing, operating, and servicing a solar DHW system are the same as for conventional DHW systems.

The major exception is that some solar DHW systems use toxic or nonpotable heat transfer fluids. In this case, you must take particular precautions.

Electrical Safety

Connections and circuit protection at the service box must meet local code requirements. The system controller should have its own properly grounded and protected power outlet. Installation personnel should not stand on a damp floor while working on a circuit. A dry wooden platform should be provided under the service box, and the box should be located far enough from the storage tanks and plumbing so that leaks and drainage will not dampen the floor near it.

Maintenance Personnel Safety

Components should be located to assure safe, easy access to collectors, pumps, storage tanks, and the control system for periodic inspection, maintenance, and replacement. To make maintenance and troubleshooting faster and safer, post a chart near the system listing the appropriate safe pressures, fill levels, flow directions, and other information for all crucial valves and other components. All crucial valves and components also should have such information attached on clearly labeled tags, according to HUD's IMPS.

The main fuse should be pulled when maintenance personnel work on the service box. When working on one circuit, either remove the fuse or trip the circuit breaker.

Pedestrian and Visitor Safety

All surfaces with operating temperatures of 120°F. or above that cannot be insulated (such as collectors if ground mounted) should be marked as potential hazards to prevent burns. All temperature and/or pressure relief valves should be located so that pedestrians and equipment will not be harmed when the valves vent. If local snow loads are more than 20 pounds per square foot, adequate protection should be provided for shrubbery and for pedestrians who might be endangered by snow or ice sliding off roof-mounted collectors.

Heat Transfer Fluid Safety

Heat transfer fluids should be safe and stable at both stagnation and normal running temperatures. Toxic heat transfer fluids should be discharged into dry well storage or sanitary drain in a manner acceptable to local codes. A harmless dye should be added to all toxic or nonpotable heat transfer fluids if they are not supplied with color added.

WARNING!

All outlets and faucets on nonpotable or toxic fluid lines should be wired closed and tagged "DANGER—NOT DRINKABLE." As an added safety precaution, the ends of pipes draining toxic heat transfer fluids SHOULD NOT BE THREADED. This will prevent using hose caps and hookups for domestic usage.

There should be an air gap of at least six inches between the end of a pipe draining toxic heat transfer fluid and the drain. This will prevent any fluid from being siphoned back into the system. If the toxic fluid drain is accessible to children or pets, shield it with wire screen or other material to prevent poisoning. An approved backflow preventer at the cold water supply inlet may be required by local codes. The layout of the system must be designed so that direct connection between system wastes and the potable water supply is impossible.

Remember, there must be a double-walled heat exchanger or some other approved method of separating toxic and nonpotable heat transfer fluids from the heated potable water. Single-walled heat exchangers with extra thick walls or those that rely on potable water pressure to prevent contamination are not acceptable to HUD's IMPS.

User Safety

A tempering valve should be installed to limit the exit temperature of the domestic hot water to prevent scalding. Brass caps should be used on all drain valves.

The vacuum relief valves required to prevent the collapse of storage or expansion tanks must not be allowed to freeze.

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CHECK-OUT AND CHARGE-UP

When installation is completed, the system must be checked for leaks before it is charged for use. The type of system will determine what leak test and charge-up procedure to follow. Remember to keep the collectors covered. Follow procedures recommended in the manufacturer's instructions.

Closed-Loop System—Hydrostatic Test

All elastomeric pipe insulation must be pulled back from joints and component connections and held by clamps during leak testing. Be sure to remove all gauges, relief valves, and expansion tanks and plug the openings. These may be damaged if tested at pressures greater than their design limits. Shut all fill and drain valves.

Conduct a hydrostatic test of the system as described in IMPS S-615-10.10.1. Cover the collectors (they must be at a constant temperature). Fill the system and bring up to test pressure. For best results, test for one hour at 1½ times maximum design pressure.

CAUTION!

Do not use water to test silicone or oil systems because any water left in the system will separate out and could boil, freeze, or cause corrosion. Because water/glycol mixtures will leak in situations when water will not, use only those mixtures to test systems using them as heat transfer fluids.

Check all joints. If leaks are observed, tighten or resolder and retest. After the test, drain the system completely into a container in order to measure the system volume. This will determine the proper amount of heat transfer fluid needed (or the amount of glycol needed to make another batch of anti-freeze mixture) to refill the collector loop.

Draindown System—Drain Line Test

Because all lines must drain completely by gravity, be sure that all pipes are pitched properly, that solenoid valves are operating properly by applying operating current. and that there are no obstructions in the system.

Air System—Leak Detection

Leaks in the ducts of solar air systems are more difficult to detect than leaks in systems using liquid heat transfer fluids. Since leaks can lower system efficiency, all sheet metal ducts must be fabricated and fitted with special care.

Before insulation is applied, turn fans on and slowly pass a wet hand over all joints and seams to feel air leaks. If possible, blow a scented nontoxic gas through the system and locate the leaks by smelling at all potential leak areas.

WARNING! Because of the hazards involved, using an open candle flame to detect leaks is definitely NOT recommended.

The potable water plumbing of air collector solar DHW systems is tested as described above.

Pumps and Sensors

Proper cycling of the system can be tested by installing an elapsed time meter. It can be removed after a few weeks when you have established that the pumps and sensors are operating correctly. An installer who does many solar DHW installations would find an elapsed time meter a useful investment.

The meter should indicate pump operation during the sunny parts of the day (primarily between 9:00 A.M. and 3:00 P.M.) and no operation at night. If the pump runs at night or continuously, it is a clear indication that something is wrong with the control system. The most likely cause is reversal of the collector and storage sensor to the controller.

Sensors that are faulty or make unintended thermal contact with a heat source are a major source of control problems. Sensors must be tightly attached. If you suspect a faulty sensor, dip it alternately in hot and cold water to see whether the pump starts or stops.

CHARGING THE SYSTEM

After the system is leak tested, it must be flushed out and then charged. The collector loop can be filled either manually from the roof or by pumping from the lowest point in the system.

Flushing the System

All metal filings, flux, solder, silt, and other contaminants not cleaned out of the system during hydrostatic and drain line testing must be flushed out. Check to see that collectors are still covered and that the controller is OFF.

Open both fill and drain valves and close the isolation valve between them. Fill a large plastic bucket with clean water. Connect a small, hi-head self-priming pump (of the type used to pump out cellars) to the fill valve in the direction of flow with the feed line hose in the bucket. Or you may attach the fill hose directly to your water supply. Attach another hose to the drain valve and bring to a drain. Run for 10-15 minutes. Remove and clean the strainer screens. Do not use water to flush out any systems or parts of systems that use hydrocarbon or silicone heat transfer fluids.

Filling From the Bottom

To fill, repeat the flushing procedure with a bucket of heat transfer fluid (Figure 9.1). Run the pump for about 20 minutes to purge air from the system, recirculating the same fluid. Close the drain valve. Allow the system to pressurize to the desired pressure. Close the return drain valve and open the isolation valve. Shut off the pump and cap and tag the drain with fluid type, fill date, and emergency procedures (Figure 9.2). Post this information on a wall chart by the switch box. Turn on the controller, set it to automatic mode, and remove collector covers. Check the elapsed time meter for proper system operation.

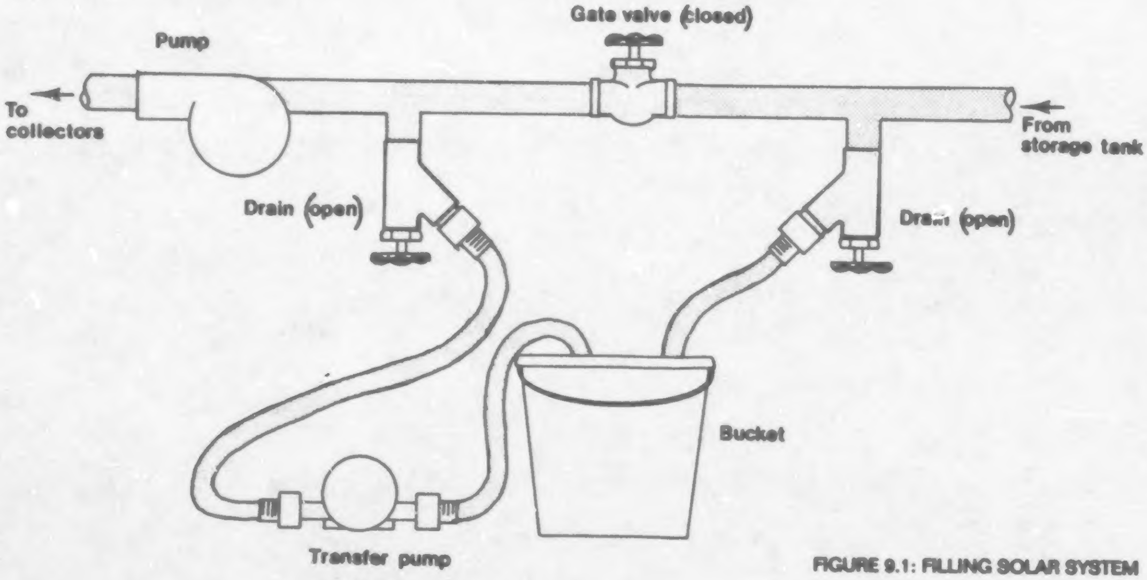

FIGURE 9.1: FILLING SOLAR SYSTEM

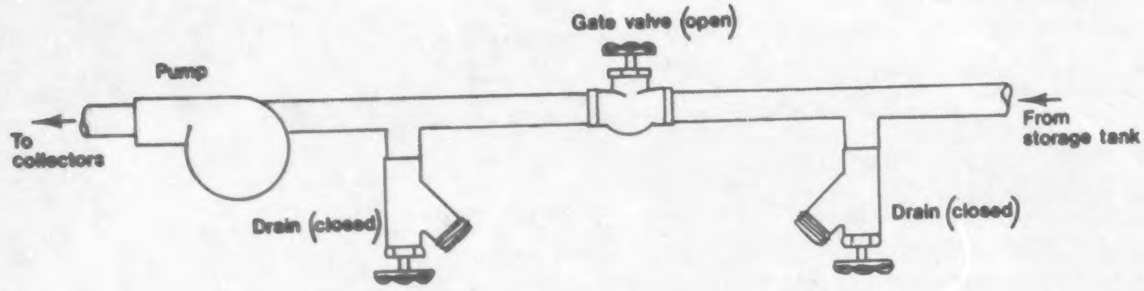

FIGURE 9.2: SYSTEM IN OPERATING POSITION

Filling From the Roof or High End of the System

Filling can be accomplished without trapping air in the system. Install a fill valve at the high point in the system. Pour the fluid in and close the valve. This procedure is used primarily with nonpotable or toxic heat transfer fluids. Beware of staining or damaging roofing material and take proper precautions for your own safety.

Charging Follow-up

Be sure to check the system thoroughly after two days of operation. Note that air may continue to be purged from the system and that system pressure may drop slightly. Check the elapsed time meter for proper operation.

Connecting the Solar DHW System to the Conventional System

Drain and flush the conventional DHW tank. Turn off the water and power. Close the drain and make the connections. Clean off excess flux and solder. Flush out system thoroughly. Turn on the water and power and fill the system.

MAINTENANCE

All solar DHW systems should be inspected at least once yearly in addition to any periodic maintenance that may be required for the components. Keep a log of all maintenance performed on the system. The homeowner should be instructed in the proper start-up, routine maintenance, and shutdown (including emergency) procedures.

Collectors

The outer glazing of collectors should be cleaned regularly, with intervals dependent on weather, insects, nearness to trees, and air pollution. Clean the collectors when they're not too hot—early in the morning or on a cloudy day. Tempered glass can be cleaned with numerous commercially available products, but some plastics require careful choice of cleaning compounds. Acrylic, for example, should be cleaned only with mild soap and water, followed by a water rinse. Give the manufacturer's recommended cleaning instructions to the homeowner. Leaves, seeds, dust from nearby construction operations, and other debris should be carefully swept off the collectors. However, sweeping may damage some plastic films.

Inspect the collector sensor periodically to be sure it is making good thermal contact. Inspect the absorber plate and look for surface peeling, crazing, or scratching of the surface coating, if any. The manufacturer may be able to recommend a proper touch-up paint to prevent the efficiency of the collector array from dropping seriously. If the collector tubing is loose or is no longer making contact with the absorber plate, contact the manufacturer for repair instructions. Heat transfer cement might be used to fill in the gaps.

If the glazing is broken, shut down the system immediately and cover the collector array with a sheet, tarp, or opaque plastic dropcloth until the glazing can be replaced.

Heat Transfer Fluids

Test and replace heat transfer fluid at manufacturer's suggested intervals. If the replacement interval for a corrosion inhibitor is shorter than the heat transfer fluid interval, replace both at the shorter interval.

Water/glycol mixtures should be checked for pH, inhibitor, and solution concentration (specific gravity) twice a year. They generally need replacing only each year or two.

CAUTION! Check fluids immediately after they have been subjected to near-stagnation temperature to see if any high temperature breakdown of the glycols to acid has occurred.

Pumps and Blowers

Some circulator pumps are sealed and permanently lubricated, others are lubricated by the heat transfer fluid, and still others require periodic lubrication. Check the manufacturer's literature for recommended lubrication schedules, if any. Blowers in air systems also may be sealed or may require lubrication. Check on suggested schedules.

Pressure Gauges

Check the system pressure periodically to see if it falls within the proper range.

Plumbing

Inspect fittings, insulation, and seals once a year for visible leaks. If a leak appears, shut down the system immediately for repairs.

Air Vents

Check for clean floats and seals. An air vent will sputter audibly if any dirt or debris is caught in the mechanism. Caps should be checked to make sure that they are still loose enough to allow air out of the system. Screw caps tight by hand and then loosen them TWO TURNS. If the float mechanism becomes inoperative, the air vent must be replaced.

Valves

Valves containing filters must be taken apart periodically to clean the screens. Be sure solenoid and automatically controlled valves are not getting wet. If such electrically operated valves short out, they must be replaced.

Storage Tanks

Tanks present few maintenance problems. Drain and flush tanks once a year. Make sure that the tank thermal insulation has not split or loosened or that the duct tape has not pulled loose. Check to see that the tank temperature sensor is making good thermal contact.

Specific Maintenance for Draindown Systems

Check system pressure and its relation to the setting on the pressure switch. Adjust if necessary. Remove a convenient fitting and check for scaling. Check for clean operation of solenoid valves by unplugging the line from the auxiliary outlet. Make certain that the drain runs freely.

INSTALLATION CHECKLIST

NOTE: Although it is mandatory standard procedure to consult the installation, operations, and maintenance instructions supplied by the manufacturer for each approved system, the following general checklist will serve as a useful guide for installing a typical solar DHW system. For more detailed information, consult HUD's Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems, Volume 5 (4930.2).

YES NO

1. SITING AND ORIENTATION

________ ________ 1-1. Are collectors oriented in a proper southerly direction?

DISCUSSION: Most manufacturers recommend true (not magnetic) south plus or minus 15°. Variations outside these limits reduce the efficiency of the system.

________ ________ 1-2. Do solar collectors have an unobstructed view in a southerly direction between 9:00 A.M. and 3:00 P.M.?

DISCUSSION: While shading problems are possible all year, low winter sun angles may cast shadows of distant obstructions across the collectors that would not be a problem in summer. Remember that trees which shed leaves in the fall are less prone to create such problems than evergreens.

________ ________ 1-3. Are collectors tilted within acceptable limits?

DISCUSSION: Most manufacturers recommend latitude plus up to 10° for domestic hot water installations. Variations outside these limits may reduce the efficiency of the system. Increasing the tilt favors winter energy collection, decreasing it favors summer collection.

YES NO

1-4. Are system components located in such a manner as to harmonize with surroundings, to minimize vandalism and obstruction to pedestrian or vehicular traffic, and to facilitate emergency access? ________ ________

DISCUSSION: Solar energy system components may include elements which are large and visually dominant when viewed from off-site. If not carefully designed and located, such elements can produce a detrimental effect on the overall appearance of a residential area. The potential hazard and nuisance of collector reflections should not be ignored when planning system locations. Also, solar hot water systems should not block exits, roads, or walkways and, since they might be said to constitute an "attractive nuisance" (like an unfenced swimming pool), should be fenced off to prevent unauthorized access.

1-5. Are system components located in such a manner as to allow easy access for cleaning, adjusting, servicing, examination, replacement or repair, especially without trespassing on adjoining property? ________ ________

DISCUSSION: Components should not be located in places which are difficult to reach. Storage tanks may need periodic inspection, maintenance, and possible replacement. Care must be taken that installers do not damage existing roofing or flashing.

1-6. Is there safe and easy access to gutters, downspouts, flashing, and caulked joints to allow minor repairs and preventative maintenance? ________ ________

1-7. Are collectors located to minimize heat losses?

DISCUSSION: In order to avoid heat losses, the location of the solar collector should be planned to avoid low spots where freezing ground fog can collect or unprotected ridges where winds can be more extreme.

1-8. If ground-mounted, are collectors located to minimize interference from drifting snow, leaves, and debris? ________ ________

DISCUSSION: Collector surfaces are often smooth and slippery, warmer than their surroundings, and located in elevated positions at steep angles. Adequate space should be provided for melting snow to slide off collectors. Poorly placed ground-mounted collectors and components may encounter snow cover and drifting problems beyond the capabilities of collectors to clean themselves. Collectors should be a minimum of 18 inches above ground level at their lowest point to reduce drift coverage and mud splashing.

1-9. If roof-mounted, are existing roof structures capable of supporting the additional load imposed by the collectors? ________ ________

YES	NO		
		2. COLLECTOR MOUNTING	
________	________	2-1.	Is the framework constructed to support collectors under anticipated extreme weather conditions (wind loading up to 100 MPH, ice, rain, etc.)?
		DISCUSSION:	A tilted collector array can markedly increase the wind loading (both positive and negative) imposed on a roof.
________	________	2-2.	Has the framework been treated to resist corrosion?
________	________	2-3.	Are joints between the framework and the rest of the building caulked and/or flashed to prevent water leakage and are collectors installed so as not to contribute to moisture build-up, rotting, or deterioration of the roof or wall of the building?
		DISCUSSION:	All holes in the roof should be flashed and sealed according to the National Roofing Contractors Association Manual of Roofing Practices, 1970.
________	________	2-4.	Are collectors installed so that water flowing off warm collector surfaces cannot freeze in cold weather and damage roof or wall surfaces?
		DISCUSSION:	Keep collectors several feet from eaves to prevent ice dams from forming and backing water up under shingles. In the case of ground-mounted systems, a gutter and downspout might be necessary to prevent excessive erosion around the footings.
________	________	2-5.	Have collectors been mounted with weep holes (if provided) at the lowest end of the collector?
		DISCUSSION:	Proper provision for runoff of condensation within the collectors minimizes the problem of fogging of the inside of the collector glazing. Holes should be blocked with glass fiber to prevent entry of dirt.
________	________	2-6.	In areas that have snow loads over 20 pounds per square foot or greater, have provisions been made to deflect snow or ice that may slide off roof-mounted components and endanger vehicles or pedestrians?
		3. PIPING AND VALVES	
________	________	3-1.	Have the required building, plumbing, and electrical permits (if necessary) been obtained prior to the start of installation?
		DISCUSSION:	In some localities it may be necessary to supply background information on the operation of solar domestic hot water systems to the local building inspector.
________	________	3-2.	Have solar components been ordered well in advance of the scheduled date to begin installation?

YES NO

DISCUSSION: Installers frequently underestimate the time required to complete their first few installations. Special order equipment should be received before installation begins.

3-3. Are connections to potable water lines being made by a licensed plumber where required by local codes? __________ __________

3-4. Is all piping properly insulated to maintain system efficiency? __________ __________

DISCUSSION: All piping should be insulated to at least R-4. The first 5-10 feet of pipe coming from the conventional water heater tank also should be insulated.

3-5. Is all exposed insulation protected from weather damage? __________ __________

DISCUSSION: Fiberglass, rigid pipe insulation should be wrapped with weather-protective material. Neoprene insulation must be painted with a flexible finish or wrapped to prevent ultraviolet degradation. It is important to seal all joints, because water seepage will damage insulation and reduce system efficiency.

3-6. Are sufficient pipe hangers, supports, and expansion devices provided to compensate for thermal effects? __________ __________

DISCUSSION: Insulation should not be interrupted for pipe hangers or supports. Pipes should be insulated as completely as possible. Straight pipe runs of 100 feet or more call for an expansion joint and anchors to avoid pipe or equipment damage.

3-7. In ground-mounted systems, are insulated pipes to and from collectors buried below the frost lines? __________ __________

DISCUSSION: Not only do unburied pipes present a poor appearance, but inadequately buried pipes may be subjected to abnormal stresses due to frost heaving (insulation can absorb some stress). Because buried pipe insulation is subject to absorption of ground water, use only thoroughly waterproofed closed-cell foam insulation. Local codes may prohibit normal 95-5 or 50-50 soldered joints underground. Use 45 percent silver solder, brazing alloys, or whatever local codes require. Take care when backfilling the ditch that rocks and construction debris do not touch pipes and create stress points.

3-8. Is piping for draindown systems properly pitched to facilitate draining of fluid from the collectors? __________ __________

DISCUSSION: Draindown systems with piping not buried below the frost line are vulnerable to frost heaving, changes in the piping pitch, air lock, and subsequent incomplete draindown resulting in frozen pipes, and collector damage. Closed loop systems should also be pitched to facilitate draining, filling, and venting.

3-9. If ground-mounted collectors are used, is the run of pipe to storage and back reduced to the absolute minimum? __________ __________

DISCUSSION: Long pipe runs between collectors and storage tanks reduce the efficiency of the system by increasing heat losses and

YES **NO**

pressure drops. If the run from collectors to storage and back is greater than 100 feet, use thicker insulation and consult standard plumbing tables for pipe size required. Provisions must be made for expansion.

________ ________ 3-10. Have isolation valves been provided so that major components of the system (pumps, heat exchangers, storage tank) can be serviced without system draindown?

________ ________ 3-11. Have air bleed valves been provided at high points in the system so that air can be removed from the liquid circulation loop during both filling and normal operation?

________ ________ 3-12. Have suitable connections been supplied for filling, flushing, and draining both the collector loop and the potable water piping of the system?

________ ________ 3-13. Has piping been leak tested to 1½ times system design pressure for at least 1 hour at constant temperature (with collectors covered) prior to backfilling and insulating?

________ ________ 3-14. Has corrosion between dissimilar metals been avoided by the use of suitable inhibitors in the system as well as dielectric washers in the mounting?

________ ________ 3-15. Has care been taken not to short out the insulating effect of dielectric washers between dissimilar metals by pipe hangers, control systems connections, etc.?

________ ________ 3-16. Will heat transfer fluids be safe and stable at both stagnation temperature and normal running temperatures?

DISCUSSION: Glycol heat transfer fluids should not be subjected to more than 250°F, because this will shorten service life. The flash point of any oil should be compared with the maximum collector stagnation temperature, particularly if the collector manifold is inside the building envelope.

________ ________ 3-17. If a system using antifreeze is used, have a fill valve and a drain (for sampling) been provided in the collector loop?

DISCUSSION: An extra gate valve and drain may have to be installed to blow out the system with compressed air if it is not pitched to drain properly. Make sure that the fill port is upstream of the check valve to prevent air being trapped in the system when filling the collector loop with antifreeze.

________ ________ 3-18. Has a tempering valve or other temperature limiting device been installed to limit exit temperature of the hot water to a safe level?

YES NO

DISCUSSION: Reducing the output water temperature prevents scalding, saves energy, and may be required by law for unregulated DHW water heaters.

3-19. If a system containing antifreeze is used, have threaded joints been taped with tightly drawn Teflon[R] tape? ______ ______

DISCUSSION: Antifreeze solutions will often leak through joints that normally will contain water. Therefore, special attention should be paid to joint leakage.

3-20. Are all systems, subsystems, and components clearly labeled with appropriate flow direction, fill weight, pressure, temperature, and other information useful for servicing or routine maintenance? ______ ______

3-21. Are there vacuum relief valves in the system to prevent the collapse of storage or expansion tanks? ______ ______

3-22. Has care been taken to install the circulator pumps so that fluid is flowing in the proper direction? ______ ______

DISCUSSION: Improper pump installation is a common problem. Check to see that the small paper gasket in a Bell and Gossett[R] pump (if used) is still intact after rotating the pump for proper flow direction. Pumps manufactured by other firms will indicate flow direction by another method. Isolate pump vibration from structural members.

3-23. Has the expansion tank been located on the suction side of the pump? ______ ______

3-24. Has a check valve been installed in the collector loop to prevent reverse circulation by thermosiphoning at night? ______ ______

DISCUSSION: Such reverse circulation causes system inefficiency and heat losses.

3-25. Are vacuum relief valves protected from freezing? ______ ______

4. STORAGE TANK

4-1. Is the storage tank insulated to at least R-11? ______ ______

4-2. Are the piping connections to the tank located to promote thermal stratification? ______ ______

DISCUSSION: The cold city water inlet should be at the bottom of the storage tank, as should the pickup for the cold water to be supplied to the heat exchanger or collector. Hot fluid returning from the heat exchanger or collector should be introduced at the top of the tank. Do not block the top of a gas heater or the entrance of combustion air at its base.

4-3. If a storage tank is installed on a roof or in an attic, is it provided with a drip pan and an outlet to an adequate drain? ______ ______

YES	NO		
________	________	4-4.	Is the storage tank properly connected to the conventional water heater?
		DISCUSSION:	To maximize system efficiency, the collector loop must be permitted to operate independently of the hot water demand. A separate tank, in addition to the conventional heater tank, will provide greatest system efficiency. The higher end of the solar storage tank, through which the collector loop circulates, may be connected to the low end of the conventional hot water tank so that cold city water goes into the solar tank and forces the preheated water from the top of the solar tank into the conventional tank.
________	________	4-5.	Are buried storage tanks anchored to prevent flotation in case of high groundwater levels?

5. SYSTEM SAFETY

YES	NO		
________	________	5-1.	Are all surfaces with running temperatures at 120°F. or higher isolated from pedestrian traffic in order to prevent burns?
________	________	5-2.	Are temperature and/or pressure relief valves installed so that pedestrians or equipment are not exposed to effects of venting valves?
________	________	5-3.	Are temperature and/or pressure relief valves installed so as to prevent system pressures from rising above working pressure and temperatures?
________	________	5-4.	When toxic or flammable fluids are used in the system, will fluids overflow or discharge into sewers or storage in a manner acceptable to the local applicable codes?
		DISCUSSION:	As an added safety precaution, the end of the pipe draining the toxic or flammable heat transfer fluid should NOT BE THREADED to prevent any type of hose hookups for any accidental use.
________	________	5-5.	If supplied water pressure is in excess of 80 pounds per square inch or the working pressure rating of any system components, has an approved pressure regulator preceded by an adequate strainer been installed?
		DISCUSSION:	Pressure should be reduced below 80 psig or system working pressure. Each regulator and strainer should be located and isolated by valves so that the strainer is readily accessible for cleaning without removing the regulator or strainer body or disconnecting the supply piping.
________	________	5-6.	Has the system been designed so that any direct connection between wastes from the system and potable water is impossible?

YES NO

5-7. Is there an approved backflow preventer at the cold water supply inlet if required? ________ ________

DISCUSSION: When a backflow preventer is installed, an expansion tank may be required for the hot water system.

5-8. Is there a double-walled heat exchanger in the system or another approved method of separating nonpotable heat transfer fluids from potable water? ________ ________

DISCUSSION: HUD's Intermediate Minimum Property Standards notes that single-walled heat exchanger designs that rely solely on potable water pressure or extra thick walls to prevent contamination are not acceptable.

5-9. Have all outlets and faucets on the nonpotable water lines of the system that might be used by mistake for drinking or domestic uses been marked "DANGER—WATER NOT DRINKABLE"? ________ ________

DISCUSSION: It is suggested that valve handles be removed or tool-operated valves be added if the system is accessible to children too young to read.

5-10. If hazardous fluids are used in the system, have proper procedures for their use, including first-aid, handling, and safe disposal been supplied to the owner? ________ ________

DISCUSSION: Nonpotable heat transfer fluids should be colored as a safety precaution.

5-11. Is adequate drainage available in the collector piping array for leaks in collectors and discharges from pressure relief valves? ________ ________

DISCUSSION: Suitable high-temperature weather-resistant piping should be utilized. Because some oils are corrosive to asphalt shingles, take special care when oils are used in the collector loop and collectors are roof-mounted.

6. ELECTRICAL SYSTEM

6-1. Does field electrical wiring comply with all applicable local codes and equipment manufacturer's recommendations? ________ ________

6-2. Is there a properly grounded and protected power outlet for the system controls? ________ ________

6-3. Has control circuit wiring been color-coded or otherwise labeled so that wires are readily traceable? ________ ________

6-4. Are the sensors for collectors and storage tank attached tightly for the best possible thermal transfer and located per equipment manufacturer's instructions? ________ ________

YES	NO		
______	______	6-5.	Is the collector temperature sensor located in a collector or near the exit from the collector array?

7. CHECKOUT AND START-UP OF SYSTEM

YES	NO		
______	______	7-1.	Has a person qualified in both solar and conventional hot water systems put the system through at least one start-up and shutdown cycle, including putting the system through all modes of operation?
		DISCUSSION:	Installation labor should include time allotted to balance the system for proper flow. Temperature differences under known conditions can be used in lieu of a flow meter.
______	______	7-2.	Has the owner been instructed in the proper start-up and shutdown procedures, including the operation of emergency shutdown devices, and fully instructed in the importance of routine maintenance of the system, including cleaning collector glazing and other components, draining and refilling the system, air venting, corrosion control, and other procedures?
		DISCUSSION:	A clear understanding between installer and owner as to what task could or should be undertaken by each party is a valuable tool for increasing solar business. Some owners may be interested in doing some or all of their system's routine maintenance. Others will gladly enter a service contract arrangement when the full extent of the routine maintenance tasks is clearly understood. While you might be more interested in an installation—rather than maintenance—based business, remember that regular service calls give the owner an opportunity to have a system "tuned" to greatest efficiency.
______	______	7-3.	Do operating instructions include provisions for the system if the owner leaves for a vacation and hot water use is nil?
______	______	7-4.	Has the system been designed so that both solar and conventional systems can operate independently of each other?

GLOSSARY AND SYMBOLS

APPENDIX A

Absorbent—the less volatile of the two working fluids used in an absorption cooling device.

Absorber—the surface in a collector that absorbs solar radiation and converts it to heat energy; generally, matte black surfaces are good absorbers and emitters of thermal radiation while white and metallic surfaces are not (see Selective Surface).

Absorptance—the ratio of energy absorbed by a surface to the energy striking it.

Active System—a solar heating or cooling system that requires external mechanical power to move the collected heat.

Air-type Collector—a collector that uses air as the heat transfer fluid.

Altitude—the angular distance from the horizon to the sun.

Ambient Temperature—the temperature of surrounding outside air.

ASHRAE—abbreviation for the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Auxiliary Heat—the extra heat provided by a conventional heating system for periods of cloudiness or intense cold when a solar heating system cannot provide enough.

Azimuth—the angular distance between true south and the point on the horizon directly below the sun.

British Thermal Unit (BTU)—the quantity of heat needed to raise the temperature of one pound of water one degree Fahrenheit.

Calorie—the quantity of heat needed to raise the temperature of one gram of water one degree Celsius.

Closed Loop—any loop in the system which is not exposed to the atmosphere.

Coefficient of Heat Transmission—the rate of heat loss in BTU per hour through a square foot of wall or other building surface when the difference between indoor and outdoor air temperatures is one degree Fahrenheit.

Collector—a device that collects solar radiation and converts it into heat.

Collector Efficiency—the ratio of usable heat energy extracted from a collector to the solar energy striking the cover.

Collector Tilt—the angle between the horizontal plane and the solar collector plane.

Concentrating Collector—a device which concentrates the sun's rays on an absorber surface which is significantly smaller than the overall collector area.

Conductance—the rate of heat flow (in BTUs per hour) through an object when a 1°F. temperature difference is maintained between the sides of the object.

Conduction—the flow of heat due to temperature variations within a material.

Conductivity (k-value)—a measure of the ability of a material to permit conduction heat flow through it.

Convection—the motion of fluid such as gas or liquid by which heat may be transported (see Gravity Convection).

Cover Plate—a sheet of glass or transparent plastic placed above the absorber in a flat-plate collector (see Absorber and Collector).

Degree-day—a unit that represents a 1°F. deviation from some fixed reference point (usually 65°F.) in the mean daily outdoor temperature.

Demand Load—domestic water heating needs to be supplied by solar or conventional energy.

Diffuse Radiation—indirect sunlight that is scattered from air molecules, dust, and water vapor.

Direct Radiation—solar radiation that comes straight from the sun, casting shadows on a clear day.

Domestic Water Pressure—the pressure of the potable water within the building from sources not related to the solar domestic hot water system.

Double-glazed—covered by two panes of glass or other transparent material.

Double Wall Separation—heat exchangers utilizing non-potable heat transfer fluids are separated from the potable water system by use of two walls between the fluids.

Emittance—a measure of the propensity of a material to radiate energy to its surroundings.

Flat-plate Collector—a solar collection device in which sunlight is converted into heat on a plane surface without the aid of reflecting surfaces to concentrate the rays (see Collector).

Forced Convection—the transfer of heat by the flow of fluids (such as air or water) driven by fans, blowers, or pumps.

Galvanic Corrosion—the condition caused as a result of a conducting liquid making contact with two different metals which are not properly isolated physically and/or electrically.

Getters—(sacrificial anodes)—a column or cartridge containing an active metal which will be sacrificed to protect some other metal in the system against galvanic corrosion.

Gravity Convection—the natural movement of heat that occurs when a warm fluid rises and a cool fluid sinks under the influence of gravity (see Convection).

Header—the pipe that runs across the edge of an array of solar collectors, gathering (or distributing) the heat transfer fluid from (or to) the risers in the individual collectors. This insures that equal flow rates and pressure are maintained (see Risers).

Heat Capacity—a property of a material denoting its ability to absorb heat.

Heat Exchanger—a device, such as a coiled copper tube immersed in a tank of water, that is used to transfer heat from one fluid to another through a separating wall.

Heat Storage—a device or medium that absorbs collected solar heat and stores it for use during periods of inclement or cold weather.

Heat Storage Capacity—the amount of heat which can be stored by a material.

Heating Season—the period from early fall to late spring (in the Northern Hemisphere) during which additional heat is needed to keep a house comfortable for its occupants.

Hybrid Solar Energy System—a system that uses both active and passive methods in its operation (see Active System and Passive System).

Infrared Radiation—electromagnetic radiation from the sun that has wavelengths slightly longer than visible light.

Insolation—the total amount of solar radiation—direct, diffused, and reflected—striking a surface exposed to the sky.

Insulation—a material with high resistance (R-value) to heat flow.

Isogonic Chart—shows magnetic compass deviations from true north.

k-value—(see Conductivity) BTU/hr/ft²/F° per inch.

Kilowatt—a measure of power equal to one thousand watts, approximately 1 1/3 horsepower, usually applied to electricity.

Kilowatt-hour (kwh)—the amount of energy equivalent to 1 kilowatt of power being used for one hour; 3,413 BTU.

Langley—a measure of solar radiation; equal to one calorie per square centimeter.

Liquid-type Collector—a collector using a liquid as the heat transfer fluid (see Collector).

Natural Convection—see Gravity Convection.

Open System—some part of the system is vented to the atmosphere, or the system contains fresh or changeable water.

Passive System—an assembly of natural and architectural components which converts solar energy into usable or storable thermal energy (heat) without mechanical power.

Percent Possible Sunshine—the percentage of daytime hours during which there is enough direct solar radiation to cast a shadow (see Direct Radiation).

Pyranometer—an instrument for measuring solar radiation (see Solar Radiation).

Radiation—the flow of energy across open space via electromagnetic waves such as visible light.

Reflected Radiation—sunlight that is reflected from surrounding trees, terrain, or buildings.

Refrigerant—a liquid such as Freon^{R} that is used in cooling devices to absorb heat from surrounding air or liquids.

Reradiation—radiation resulting from the emission of previously absorbed radiation.

Resistance (R-value)—the tendency of a material to retard the flow of heat.

Retrofitting—the addition of a solar heating or cooling system to an existing building.

Risers—the flow channels or pipes that distribute the heat transfer liquid from the headers across the face of an absorber plate (see Header).

R-value—see Resistance. $\dfrac{1}{\text{BTU/hr/ft}^2\text{/F.}^\circ}$

Seasonal Efficiency—the ratio, over an entire heating season, of solar energy collected and used to the solar energy striking the collector.

Selective Surface—a surface that absorbs radiation of one wavelength (for example, sunlight) but emits little radiation of another wavelength (for example, infrared); used as coating for absorber plates.

Shading Coefficient—the ratio of the solar heat gain through a specific glazing system to the total solar heat gain through a single layer of clear double-strength glass.

Solar Constant—the average intensity of solar radiation reaching the earth outside the atmosphere; amounting to two langleys or 1.94 gram-calories per square centimeter, equal to 442.4 BTU/hr/ft^2, or 1395 watts/m^2.

Solar Radiation (Solar Energy)—electromagnetic radiation emitted by the sun.

Solar Rights (Sun Rights or Solar Access)—a legal issue concerning the right of access to sunlight.

Specific Heat—the quantity of heat, in BTU, needed to raise the temperature of one pound of a material 1°F.

Standby Heat Loss—heat lost through storage tank and piping walls (rate of heat loss differs from standing still and when moving).

Sun Path Diagram (Solar Window)—a circular projection of the sky vault, similar to a map, that can be used to determine solar positions and to calculate shading.

Thermal Radiation—electromagnetic radiation emitted by a warm body (see Infrared Radiation).

Thermistor—sensing device which changes its electrical resistance according to temperature. Used in the control system to generate input data on collector and storage tank temperatures.

Thermosiphoning—the process that makes water circulate automatically between a warm collector and a cooler storage tank above it (see Gravity Convection).

Tilt Angle—the angle that a flat collector surface forms with the horizontal plane (see Collector Tilt).

Trickle-type collector—a collector in which the heat transfer fluid flows in open channels on the absorber.

Tube-in-plate Absorber—a metal absorber plate in which the

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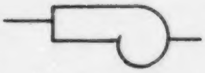
heat transfer fluid flows through passages formed in the plate itself.

Tube-type Collector—a collector in which the heat transfer liquid flows through metal tubes that are fastened to the absorber plate by solder, clamps, or other means (see Collector).

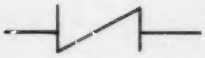
Ultraviolet Radiation—electromagnetic radiation with wavelengths slightly shorter than visible light.

Unglazed Collector—a collector without a cover plate.

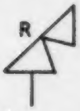
SYMBOLS



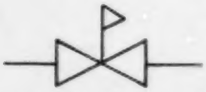
Pump



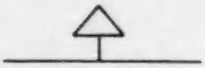
Check Valve



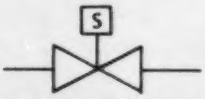
Temperature and/or Pressure Relief Valve



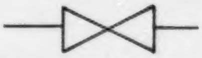
Pressure Reducing Valve



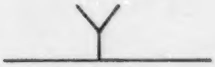
Air Vent (Air Eliminator)



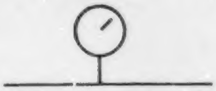
Solenoid Valve



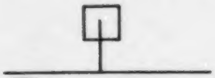
Isolation Valve



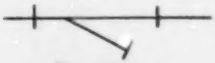
Fill Valve



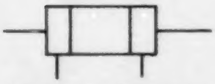
Pressure Gauge



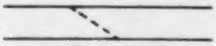
Thermometer



Strainer



Heat Exchanger



Damper

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APPENDIX C

SOLAR INSTALLER TOOL KIT

Here is a suggested list of tools you will need to successfully complete the installation of your solar hot water system.

- Compass
- Fire extinguisher
- Gas torch & igniter
- Tubing cutter with reamer or wire brush
- Steel wool or emery cloth
- Hacksaw
- Pipe wrenches, 14"
- Electric Drill, ⅜"
- Drill bits up to ⅜" and carbide tip
- Hole saws, 2" to 3"
- 100′ extension cord
- Extension ladder
- 100′ of ⅜" rope
- No-skid shoes
- Hammer
- Level or level/inclinometer combination
- Plastic water bucket, 5-gallon
- Two washing machine hoses (female connections)
- Saw
- Tin snips
- Pliers, including Vise Grips^{R}
- Adjustable end wrenches, 14"
- Folding rule and 50′ tape
- Chalk line
- Screwdrivers, including phillips head
- Caulking gun
- Matte knife and blades
- Pencils
- Putty knife
- Wire cutter, strippers
- Volt-ohm meter
- Electrical tape
- Pipe tap; ¾" N.P.T.
- Transfer pump, 120 volt, self-priming 40′ head
- Rags

NOTE: Some installations will require additional tools and equipment.

There are a number of devices on the market to help you in siting collectors and determining shading. Among them are:

Solar Site Kit . . . Finds sun angles, calculates shading, measures roof pitch . . . Solar P.I.E., P.O. Box 506, Columbus, NC 28722, $2.95.

Solar Site Selector . . . Finds sun angles, determines shading . . . Don Lewis, P.O. Box 186, Amador City, CA 95601, $31.50.

Solar Siter Heliodon . . . model of relative motions of earth and sun . . . plans from: Solar Bookshop, Total Environmental Action, Inc., 7 Church Hill, Harrisville, NH 03450, $4.75.

Sun Angle Calculator . . . Determines sun angles . . . Libbey-Owens-Ford, Toledo, OH, 43695, $4.00.

Sun Angle Desk Top Calculator . . . Provides hours of day in sun hours and months of year, elevation in degrees from horizon and compass bearings from south . . . Zomeworks Corp., Box 712, Albuquerque, NM 87103, $65.00.

Sun Scope, II . . . Permits sun sitings for any hour, each season . . . Solar Usage Now, Inc., P.O. Box 306, Bascom, OH 44809, No. 1883, $9.95.

Roof hoists are available to lift collectors. One such device is: Handy Hoist . . . Manufactured by Sun & Roof Engineering, Inc., 11622 W. Exposition Blvd., Suite 2, West Los Angeles, CA 90064, $350.00.

APPENDIX D

SOLAR MINIMUM PROPERTY STANDARDS: HOW THEY CAN WORK FOR YOU

The rapid development of solar technology created a need among the solar designer, contractor, and installer, as well as the solar lender and appraiser and home insurance agent, for a set of standards which could apply to all solar energy systems—a complete reference guide, outlining materials, methods, and performance expected for a quality solar heating system.

To help fulfill this need, the U.S. Department of Housing and Urban Development (HUD) and the U.S. Department of Energy (DOE), with the assistance of the Office of Housing and Building Technology of the National Bureau of Standards (NBS), developed a set of Intermediate Minimum Property Standards (IMPS) which applies to dwellings equipped with solar heating and solar domestic hot water systems.

Called the HUD Intermediate Minimum Property Standards Supplement: Solar Heating and Domestic Hot Water Systems, they supplement the Minimum Property Standards for One- and Two-Family Dwellings, MPS 4900.1, and Minimum Property Standards for Multi-family Dwellings, MPS 4910.1, and are to be used in conjunction with these.

The IMPS basically augment the regular MPS, addressing those aspects of planning and design for solar housing which are different from conventional housing. They are based on current state-of-the-art technology and practice and on nationally recognized standards for solar installations.

The document is organized into chapters and divisions that parallel the general MPS to facilitate easier reference use. Most standards are accompanied by a commentary to explain further the necessity of that particular standard, and especially to clarify its implications for the solar energy system.

The IMPS went into effect in July, 1977 for all Federal Housing Administration (FHA), Veterans Administration (VA), and Farmers Home Administration (FmHA) projects utilizing solar energy systems.

They were used in the technical evaluation of submissions for the HUD solar domestic hot water initiative in 11 states and for the technical evaluation of applications received in HUD's solar demonstration project. In addition, the IMPS define the minimum quality level acceptable for single- and multi-family residences, nursing homes, and intermediate care facilities designed and constructed under HUD housing programs.

Many national trade associations have investigated for their members the impact of IMPS upon their organization. Heating, ventilating, and air conditioning (HVAC) contractors, as well as plumbers, roofers, sheet metal workers, and a host of others who have become involved in solar installation in the HUD demonstration program are now applying the standards to their operations.

Associations, such as the Northamerican Heating and Airconditioning Wholesalers Association (NHAW), the International Association of Plumbing and Mechanical Officials (IAPMO), and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), are responding to the HUD solar standards by providing feedback, by undertaking projects to interface their own codes with the IMPS, or by passing information from IMPS on to their members. The Sheet Metal and Air Conditioning Contractors Association (SMACNA), for example, keeps copies of the HUD IMPS in each of their chapter offices, making them readily available to all members.

Less apparent, perhaps, is the importance of the IMPS to the solar home mortgage lender and the solar home insurer.

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By using the IMPS, the lender can make an informed appraisal of the solar home to be mortgaged by differentiating a well-designed, properly installed solar energy system from a poorly constructed one, which may have an eventual depreciating effect upon the home.

The solar home insurer must also review the solar energy system before providing coverage. He can use the IMPS to detect areas in the construction and installation of the solar system where problems might occur and make an overall evaluation of the quality of the solar installation. The insurer can then determine the policy necessary to provide the solar homeowner with adequate coverage.

The Alternative Energy Committee of the National Association of Mutual Insurance Companies (NAMIC), for instance, uses the IMPS in their inspection of solar installation hazards to the home.

Copies of HUD Intermediate Minimum Property Standards Supplement: Solar Heating and Domestic Hot Water Systems may be purchased for $12.00 ($15.00 foreign) by ordering Stock #023-000-81007-7 from:

Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402

Anyone interested in reviewing this document can do so at HUD Regional and Area Offices, and Room 6170, HUD Headquarters, 451 7th Street, SW, Washington, DC 20410.

CREDIT

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